Opening the black box of social preferences:

Essays on underlying cognitive processes in social dilemmas

Thesis (cumulative thesis)

presented to the Faculty of Arts and Social Sciences

of the University of Zurich

for the degree of Doctor of Philosophy

by

Minou Ghaffari-Tabrizi

Accepted in the spring semester 2018

on the recommendation of the doctoral committee:

Prof. Dr. Bettina von Helversen (main supervisor)

Prof. Dr. Andreas Glöckner

Zurich, 2018

Abstract

Recent findings suggest that individual differences, particularly social preferences, systematically influence people's behavior when own interests are at conflict with others' interests (i.e., social dilemmas). Extending previous work, this dissertation addresses how social preferences affect cognitive capacities and processes in social dilemmas by studying eye movements in social interactions. It shows that individuals with a prosocial value orientation invest more effort in learning about their interaction partner's previous behavior and therefore are more likely to recall their behavior. When facing situations with a strategic component, prosocial individuals weight their partner's outcome more heavily than individualists and exhibit a stronger gaze bias towards eventually chosen strategies. Drawing from this, the current work reveals that exogenously guiding attention (bottom-up) successfully predicts other-regarding choices, while most of the variance of the link between attention and choices is explained through top-down preference formation. In sum, this dissertation extends previous knowledge on social dilemmas as it sheds light on the impact of social preferences on underlying cognitive processes and develops a preliminary understanding of attention as a driver and byproduct of social decision making.

Zusammenfassung

Bisherige Forschungsbefunde zeigen, dass individuelle Unterschiede, insbesondere soziale Präferenzen, das Entscheidungsverhalten von Menschen systematisch beeinflussen, wenn eigene Interessen mit den Interessen von anderen Personen im Konflikt stehen (soziale Dilemmas). Die vorliegende Dissertation untersucht inwiefern soziale Präferenzen kognitive Kapazitäten und Prozesse in sozialen Dilemmas beeinflussen, indem sie Augenbewegungen in sozialen Interaktionen untersucht. Die Untersuchung zeigt, dass Menschen mit einer prosozialen Wertorientierung sich stärker bemühen, Informationen über das Verhalten ihrer Interaktionspartner aufzunehmen und somit dieses Verhalten besser abrufen können. Sie zeigt auf, dass prosoziale Personen in Situationen mit einer strategischen Komponente die Folgen für ihren Partner stärker gewichten als individualistische Personen und, dass sie eine stärkere Tendenz dazu haben die Strategie anzusehen, die sie letztendlich auswählen. Darauf aufbauend zeigt die Untersuchung, dass soziale Entscheidungen durch die Beeinflussung von Aufmerksamkeit vorhergesagt werden können; gleichzeitig erklärt Aufmerksamkeit basierend auf zugrundeliegenden Präferenzen weiterhin den größten Varianzanteil von der Beziehung zwischen Aufmerksamkeit und Entscheidungen. Die Arbeit trägt zum Verständnis von sozialen Dilemmas bei, indem sie den Einfluss von sozialen Präferenzen auf kognitive Prozesse beleuchtet und die Rolle von Aufmerksamkeit in sozialen Entscheidungen untersucht.

Summary

Chapter I of this dissertation thesis shows that social preferences shape the ability to remember their interaction partner's behavior in social dilemmas. Three pre-registered studies reveal that prosocial individuals are more likely to correctly recall their social interaction partner's behavior than proself individuals. A mediation analysis further indicates that the link between memory ability and social preferences is partly driven by the extent of information search during encoding. Specifically, prosocial individuals exhibit more information search effort when encoding information about their partner's behavior than proself individuals. In sum, the results of Chapter I suggest that prosocial individuals are better able to identify free riders, which could protect them from being exploited in future interactions.

Chapter II points out that social preferences not only affect memory performance, but are also able to explain systematic differences in strategic cognitive processes. Prosocial individuals were more likely to direct their attention to the other player's payoff and the cooperative strategy than individualists. Cooperative choices were associated with shorter information search and increased attention to the cooperative strategy than defective choices. Taking temporal gaze patterns into account, the results successfully replicate the gaze cascade effect in strategic decision and additionally show that this effect tends to be stronger for prosocial individuals. In sum, Chapter II suggests that attention patterns reflect weighting processes associated with individuals' social preferences and their final choice.

A two-channel mechanism connects attention and choices (top-down and bottom-up) and Chapter III tests the respective magnitude of each channel. To disentangle these two drivers of the correlation between eye gaze and choices behavior, eye gaze is used to predict other-regarding and moral choices in two high-powered eye-tracking studies. The results show that final fixations successfully predicted choices when experimentally manipulated (bottom-up). While part of the link between attention and choices is driven by exogenously guided attention, most of the variance is explained by top-down preference formation.

Acknowledgements

First and foremost I would like to thank my supervisor Dr. Susann Fiedler for her unlimited support during this endeavor. Her dedication to her role as a supervisor and her constant availability were incredibly valuable and had a huge impact on the process of writing this dissertation. The research conditions she has created in her group and at the Max Planck Institute for Research on Collective Goods have truly been a research paradise.

Second, I would like to thank Prof. Dr. Bettina von Helversen for her valuable contribution to this dissertation. Her insightful comments and encouragement have shaped my research projects and this dissertation.

Further, I would like to thank my friends and colleagues from the MPI in Bonn, André Schmelzer, Lars Freund, Svenja Hippel, Adrian Hillenbrand and many others – your helpful comments have improved these projects immensely. Motivational table tennis and squash sessions in addition to outstanding opportunities to discuss research ideas have made my time at this institute exceptional.

Also, I have to thank my friends from Hamburg, Coralie Thomsen, Pauline Stoecker and Ernestina von Waldenfels – you never got tired of listening to my worries and celebrating my successes and I consider you the best friends anyone could ask for. Further, I want to thank my brothers, Bijan, Matin and Fardin Ghaffari. All three of them I can rely on without any exceptions and I feel very fortunate to call them my family.

Most importantly, I would like to thank my parents, Wibke and Ramin Ghaffari. None of this would have been possible without their unlimited emotional and financial support. Encouraging me to pursue my dreams and helping me to do so has been key to this endeavor.

Lenny, you know you have played a huge role in completing this dissertation. Constantly encouraging me and believing in me, even when I was in doubt, has been invaluable and I feel incredibly lucky to have you in my life.

Contents

Table legends

Figure legends

Introduction

Social dilemmas have extensively been used to study human decision. In a large literature, it is argued that many social interactions and societal problems can be distilled into a social dilemma. Specifically, social dilemmas are situations where individuals must decide whether to behave selfishly or cooperatively in consideration of outcomes for others and the future. For example, the global climate crisis can be described as a social dilemma: While everyone individually benefits from the short-term advantages of using a car or taking long showers, there are detrimental long-term consequences for everyone, such as the exasperation of the greenhouse effect or water shortages, if all individual decision makers decided to act purely according to their own interest.

The frequency with which social dilemmas are encountered in real-life roused strong scientific interest in a systematic investigation of human's behavior in such situations. Research on social dilemmas is at the intersection of various disciplines (e.g., psychology, economics, biology, law and sociology). The current dissertation adopts a perspective that is mainly based on findings from psychology and behavioral economics.

This dissertation aims to bridge the gap between the two fields by employing methodologies from both areas – economic games (economics) and eye-tracking (psychology) – to shed light on the cognitive processes that underlie people's decisions in social dilemmas. More specifically, it focuses on how individual differences, social preferences in particular, shape such decision processes. Even though there has been a fair amount of research about the effects of individual differences on decision making, it is not clear that they are fully understood yet (Appelt, Milch, Handgraaf, & Weber, 2011). The present research takes individual differences in the process of information search into account. Studying the inter-individual differences of how individuals search for, weight and remember information has become even more pertinent with digitalization being on the rise in our everyday lives, because more information than ever is available to decision makers.

Beyond individual differences, visual attention was identified as a crucial factor in other-regarding decisions (e.g., Fiedler, Glöckner, Nicklisch, & Dickert, 2013). Recently, there has been a debate as to whether the link between and attention and choice behavior is of a causal nature (Armel, Beaumel, & Rangel, 2008; Pärnamets et al., 2015, but see Newell & Le Pelley, 2018). This topic has become more relevant with the recent discussion on the involvement of psychological targeting in the US elections 2016 (González, 2017; Matz, Kosinski, Nave, & Stillwell, 2017). Supposedly, people were presented with specific pieces of information based on their digital records, in attempt to influence their political opinion. Here, it is crucial to understand the extent to which external influences have the power to influence choices via attention. Therefore, the present research systematically investigates previous causality claims and estimates whether exogenously determined characteristics of the decision situation can drive choice behavior.

In sum, the current dissertation adopts a perspective that is mainly based on findings from psychology and behavioral economics. Both disciplines have contributed to understanding cooperation in social dilemmas, but at times fail to acknowledge one another. To integrate the answers this research provides to the questions outlined above into the larger relevant literature, this introduction first reviews explanations of cooperation behavior from a theoretical and a methodological perspective. Next, it sheds light on the historical and theoretical developments of understanding cognitive processes underlying choices. Here, a special focus is placed on eye-tracking, which is the methodology used throughout this dissertation to capture eye movements. A brief overview of the auxiliary assumptions and theoretical models regarding visual attention is given. Finally, this dissertation draws special attention to the use of open and transparent research practices.

Cooperation behavior in social dilemmas

Economists have utilized a game-theoretic approach to study cooperation behavior in social dilemmas (for a review see Camerer, 2003). Using formal models, the conflict people experience in social dilemmas is captured. In its most basic form, a dictator game, two players enter a game (Kahneman, Knetsch, & Thaler, 1986). One of them is assigned the role of the dictator, while the other is the receiver. The dictator is endowed with an amount of money and can decide how much of this endowment he transfers to the receiver. The receiver has a passive role. In one of the adaptations of this game, the ultimatum game (Güth, Schmittberger, & Schwarze, 1982), the receiver can accept or decline the amount that is transferred. In case the transfer is accepted, both players receive their respective share of money. If, however, the transfer is rejected, both players receive nothing.

Adding another strategic element to the game, in the prisoner's dilemma both players' outcomes depend on the other players' behavior. The prisoner's dilemma is frequently used to capture the conflict individuals experience between self-interest and collective benefits (Rapoport & Chammah, 1965). It constitutes a two-person game in which both players can either cooperate or defect when interacting with each other, without knowledge of the other player's choice. The combined choices determine the payoffs for each player. While mutual cooperation always yields the maximum joint payoff, unilateral defection yields the maximum individual payoff for the defector (Rapoport & Chammah, 1965).

These game properties are reflected in many real-life scenarios. For example, the global climate crisis has been can be described in terms of a prisoner's dilemma (e.g. Böhringer & Vogt, 2003). All countries benefit from implementing policies reducing CO_2 emission (mutual cooperation). At the same time, any single country is often reluctant to restrict CO_2 emission while still profiting from other countries' sacrifice (unilateral defection). From a methodological viewpoint, economic games have been a popular tool to understand complex social interactions. They are mostly implemented in laboratory studies, ensuring anonymity and fully incentivized decisions. Such controlled settings offer high internal validity and thus, this dissertation utilizes economic games to investigate social interactions in Chapters I and II.

Theoretical frameworks of cooperation behavior

In attempt to explain cooperation behavior in social dilemmas, a number of theoretical frameworks were proposed. Both formal models and psychological theories have contributed to the understanding of human cooperation. As this work is focused on the intersection of economics and psychology, the most relevant theories of both areas are described in the following.

The classic game-theoretical assumption suggests that humans act as *homo oeconomicus* – rational and payoff maximizing. Based on this premise, the dominant strategy in any social dilemma is to keep all resources to you. In numerous experimental studies, however, people were found to cooperate with their counterparts in social dilemmas even if it was not payoff maximizing to do so (for overviews see Balliet, Parks, & Joireman, 2009; Bogaert, Boone, & Declerck, 2008). In order to explain these deviations from rational strategies, theories of social preferences were proposed. A number of theories have formalized that individuals' utility is not exclusively determined by one's own payoffs but also the other person's payoff. One of these formalizations models the influence of inequality aversion on utility and has been referred to as the Fehr-Schmidt model (Fehr & Schmidt, 1999). A person is inequality averse if she gets disutility from earning less than others and, possibly, gets disutility from earning more than others. The Fehr-Schmidt model captures individual's aversion against disadvantageous inequity (envy) and advantageous inequity (guilt) and assumes complete information. That is, all players have full knowledge regarding the other player's behavior and the number of a game's rounds is disclosed in the beginning.

Formally, consider a set of n players indexed by $i \in \{1,\dots, n\}$ and let $\pi = \pi_1, \dots, \pi_n$ denote the vector of monetary payoffs. The utility function of player $i \in \{1,\dots, n\}$ is given by

$$U_i = \pi_i - \alpha_i \frac{1}{n-1}\sum_{j \neq i} \max[\pi_j - \pi_i, 0] - \beta_i \frac{1}{n-1}\sum_{j \neq i} \max[\pi_j - \pi_i, 0]$$

Two parameters capture the disutility from earning less than others (α) and the disutility from earning more than others (β). The model assumes that $\alpha_i \geq \beta_i \geq 0$, meaning that a person gets more disutility from others' being better off than others' being worse off; and $\beta_i < 1$, meaning that nobody would burn money to reduce inequality when the other is worse off. Another model that incorporated inequality aversion in behavioral predictions was formalized by Bolton and Ockenfels (2000). A key feature that distinguishes the two models: While in the Fehr-Schmidt model own payoffs are compared to payoffs of individual others, it is a group average in the Bolton and Ockenfels model. Going beyond inequality aversion, other models focus on reciprocity to explain cooperation behavior in social dilemmas. For example, in Rabin's reciprocity model (Rabin, 1993) players reward kind and punish unkind intentions. More specifically, other players' kindness is evaluated based on the amount of resources they share compared to what they were expected to share. Here, beliefs about other players' actions (first-order) and beliefs about other players' beliefs (second-order) enter directly into the utility function.

Overall, the formalization of social preferences in terms of utility is an important foundation for a systematic investigation of decision making because it sharpens the notion of human behavior in social dilemmas.

Social Value Orientation

People were found to exhibit stable inter-individual differenced in their social preferences. While most people are sometimes prosocial and sometimes behave selfishly, others are always prosocial or always selfish. Specifically, it has been suggested that individuals differ in the degree that they only care about resources allocated to themselves (self-interest) or also care about resources allocated to other people (Fehr & Fischbacher, 2002). One construct capturing these individual differences is the idea of Social Value Orientation (SVO; Liebrand & McClintock, 1988). SVO refers to how people approach social dilemmas (Cox, Slockin, & Steele, 1999; A. J. Stewart & Plotkin, 2016). Depending on their SVO, people vary in the weight they attach to the outcomes they receive themselves and the outcomes allocated to other people. In terms of utility, the concept of SVO not only assumes that individuals gain utility from own payoffs (p_{own}) but also from other's payoffs (p_{other}). This assumption is formally expressed in the following utility function (Liebrand & McClintock, 1988):

$$U = w_1 \times u(p_{own}) + w_2 \times u(p_{other})$$

where u indicates a utility transformation function of outcomes and w indicates the weights assigned to own outcomes (w_1) and other's outcomes (w_2). An individual's SVO is represented by an SVO angle, which is a continuous measure computed using the weights assigned to own and other's outcomes. Based on the SVO measure typically four types of people are differentiated: *Altruists*, that only value the other's outcome, *cooperators* that assign equal weights to their own and other's outcomes, *individualists* that only assign weights to their own outcome and *competitors* that value their own outcomes as well as other's gaining less (Liebrand & McClintock, 1988; McClintock, 1972). Mostly, individuals' preferences fall between these two extreme types by weighting their own payoffs higher than the other's payoff, but not ignoring other's payoffs completely. Methodologically, the concept of SVO is based on an experimental economic game approach, assessing individuals' preferences by a series of allocation tasks. Depending on the allocation of money in a set of 24 tasks, an SVO angle is assigned to an individual. The continuous nature of the SVO angle measure offers a fine-grained prediction of behavior.

SVO has been shown to be related to individual differences in concepts associated with a range of prosocial behaviors such as empathy and perspective taking (Declerck & Bogaert, 2008), fairness concerns (De Cremer, Tyler, & Ouden, 2005), and a sense of social responsibility (De Cremer & Van Lange, 2001). Furthermore, studies using social dilemmas, have found that individuals with a more prosocial SVO are more likely to cooperate in both, laboratory and field settings (for overviews, see Balliet et al., 2009; Bogaert et al., 2008).

In sum, applying game theory to social dilemmas and formally integrating social preferences in individuals' utility functions has contributed enormously to the understanding of decision making. At the intersection of economics and psychology individual differences in decision making are explained through the concept of SVO, which draws heavily on economic methodological advances.

Cognitive processes underlying social preference choices

Beyond economic models of social preferences, psychological theories offer explanations of cooperation behavior in social dilemmas from an additional perspective. Instead of purely taking choices into account, psychological research has begun to examine the cognitive processes underlying cooperation behavior.

The cognitive revolution

The interest in processes underlying decision-making was sparked in a movement referred to as the “cognitive revolution” in the 1950s. Until then, psychology had been defined as the science of behavior and the most prevalent line of thinking was driven by the idea that cognitive processes are not observable and therefore cannot be considered objective evidence. According to Miller (2003) the cognitive revolution “brought the mind back into experimental psychology” (p. 142). The key figures of the cognitive revolution were researchers interested in opening the black box of people’s minds to learn about the underlying drivers of human behavior. Mischel (1973) was one of the first researchers who argued that it is individual differences in cognition that account for differences in behavior. His social-cognitive perspective on personality emphasizes cognitive processes in the development of personality. Prior to his work, it was argued that behavior is mostly dependent on traits, which are expected to be consistent across situations. The “trait” versus “state” question has long shaped the debate psychology with its roots in ancient philosophy. Moving away from a dichotomous view, Mischel (1973) suggested that it is not one of the two but rather a combination of the two, proposing that behavior fundamentally depends on the characteristics of a situation and the related cognitive processes.

Theoretical frameworks of cognitive processes

In attempt to advance theoretical developments and offer an explanation for behaviors, a number of theoretical frameworks regarding underlying cognitive processes of decision making were proposed. While the following is not an exhaustive listing of these theories, it rather provides a comprehensive overview of theories related to the research presented in Chapter I to III.

With growing research on cognitive processes, H. A. Simon (1972) was one of the first to identify information processing as one of the boundary conditions of rational behavior. The *bounded rationality framework* he proposed constituted a relaxation of the traditional rationality assumption. According to the bounded rationality framework, humans are limited in their cognitive capacities and can therefore only act rationally to a certain degree. Thus, it is argued that decision processes are limited by individual information processing. The framework is based on the assumption that the human mind has evolved in adaptation to evolutionary challenges. By ignoring information that is irrelevant to the decision, fitness-enhancing decisions can be made under constraints of time and resources. In line with the notion of limited processing capacity, the adaptive toolbox provides a framework for non-optimizing visions of bounded rationality and models heuristics on the actual cognitive abilities an individual has (Gigerenzer & Selten, 2002). As part of the adaptive toolbox a number of heuristics were identified that help humans to find a search direction, stop search and make a decision.

Most decision heuristics involve a conscious consideration of given information and do not speak about unconscious processes. An approach that takes account of such processes is the *dual-process* cognitive framework (for an overview see Evans, 2008). Here, decisions are conceptualized as resulting from the interaction between intuitive or reflective decision processes. While intuitive processes are usually described as fast, effortless and automatic, reflective processes refer to slower, more effortful and deliberative processes. Dual-process models are based on the concept of a two-systems framework, generally referred to as System 1 and System 2 (e.g., Kahneman & Frederick, 2002). Here, System 1 includes processes that are unconscious, rapid and automatic whereas System 2 includes conscious, slow and deliberative processes. Relating back to heuristics judgments, these are assumed to be associated with System 1 rather than System 2.

In line with the notion that decision require both automatic and deliberate processes, the *parallel constraint satisfaction* (PCS) model was developed (Glöckner & Betsch, 2008). Its key assumption is that decisions are constructed by maximizing the coherence of the mental representations of the decision problem (coherence shift). Here, information supporting the emerging decision in valued higher than contradictory information. The choice is made when a critical threshold of consistency is reached. The PCS model successfully predicts fast intuitive memory-based decisions (Glöckner & Hodges, 2011) and an extension of the model (PCS model for decision making) accounts for individual differences in adaptation with a sensitivity parameter (Glöckner, Hilbig, & Jekel, 2014).

The PCS model is related to more general evidence accumulation models of decision making, for instance the *decision field theory* (Busemeyer & Townsend, 1993). Similarly, they assume that evidence is accumulated over time until a threshold is reached and a choice is made. Within their approach, deliberation processes that results in overt choices are modeled via diffusion processes. It is in line with neural models and in contrast to algebraic utility theories. Decision field theory has frequently been employed to explain risky (e.g., Fiedler & Glöckner, 2012) and consumer choices (e.g., Berkowitsch, Scheibehenne, & Rieskamp, 2014).

Focusing on cognitive processes in social decisions, the *social exchange theory* proposed by Cosmides and Tooby (1989) is based on the assumption that cognitive capacities have evolved in adaptation to natural selection. Here, social exchange is defined as “cooperation between two or more individuals for mutual benefit” (p. 52). The authors argue that the ability to engage in successful social exchange requires a number of cognitive capacities. Besides other cognitive abilities, memory has been identified as one of the crucial capacities for cooperation. Social exchange theory has proposed that people possess a so-called cheater module, i.e., a heightened ability to remember people that cheated on them — which protects cooperative individuals from being exploited (Cosmides & Tooby, 1989). However, although some studies have found support for a cheater module (Chiappe, Brown, & Dow, 2004; Mealey, Daood, & Krage, 1996; Yamagishi, Tanida, Mashima, Shimoma, & Kanazawa, 2003), the ability to remember some people better than others does not seem to be specific for cheaters (Barclay & Lalumière, 2006; Buchner, Bell, Mehl, & Musch, 2009; Volstorf, Rieskamp, & Stevens, 2011). Chapter I of this dissertation suggests that memory benefits may not only be a function of the interaction partners' behavior but also depend on the prosocial orientation of the individual.

Thus, research on decision processes has provided a number of valuable theoretical frameworks that can be employed to discuss and integrate novel findings. Going beyond choices, theories of cognitive processes offer a more fine-grained study of decision making.

Eye movements as predictor of choice behavior

Investigating cognitive processes in even more detail, the number of studies measuring eye movements has recently spiked (Duchowski, 2017). Visual attention is defined as selectivity in perception (Orquin & Mueller Loose, 2013) and is the key interest of researchers studying eye movements (Wedel & Pieters, 2008). Research on eye movements is mostly based on the underlying assumption of the *eye-mind hypothesis* (Just & Carpenter, 1980). The eye-mind hypothesis proposes that “There is no appreciable lag between what is fixated and what is processed” (Just & Carpenter, 1980, p. 331). In other words, it assumes that what is visually attended at a specific moment is being processed in working memory at that moment. There has been some debate as to how closely related attention and eye location really are. Seemingly counterintuitive at first, attention can be moved without eye movement (Posner, 1980). The decoupling of attention from eye location has been referred to as covert attention, which is the opposite of overt attention. Even if covert attention can be observed in simple discrimination tasks (Posner, 1980), it was argued that in more complex information processing tasks, the link between attention and eye location is likely to be high (Rayner, 1998). These caveats have led to the formulation of less strong versions of the original eye-mind hypothesis in which a one-to-one relationship of attention and cognitive processing is no longer assumed (Huettig, Olivers, & Hartsuiker, 2011).

Theoretical frameworks

Many of the assumptions concerning the link between eye gaze and choice behavior are based on the *attentional drift-diffusion model* (aDDM), originally proposed by Krajbich et al. (2010). The aDDM is an evidence accumulation model, which assumes that directing the gaze towards a specific option resembles the process of collecting evidence in favor of that option. Evidence accumulation models would predict that a decision is made by accumulating stochastic information over time, until the net evidence in favor of one alternative exceeds a pre-specified threshold and a decision is made (see Figure 1). Another key idea of the aDDM is that fixations affect the value comparison process by introducing a temporary drift bias towards the fixated item in the positive domain. More precisely, fixations supposedly have a causal effect on the value comparison process. It proposes that appetitive items that are fixated on more are more likely to be chosen eventually. In particular, the relative decision value changes according to

$$V_t = V_{t-1} + d(r_x - \theta r_y) + \varepsilon_t$$

where V_t is the value of the relative decision value at time t, r_x denotes the value of the fixated item, r_y denotes the value of the unfixated item, d is constant that controls the speed of integration, θ is a parameter that reflects the bias toward the fixated option (between 0 and 1), and ε_t is white Gaussian noise.

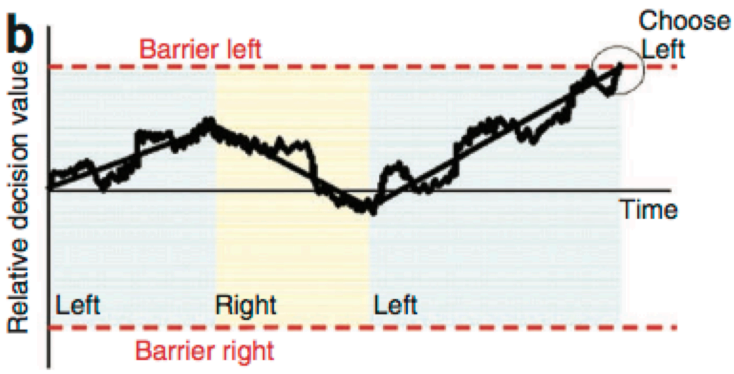

Figure 1. Attentional drift-diffusion model (aDDM). The relative decision value evolves over time with a bias towards the fixated item. When the respective threshold is reached, a choice is made. Adapted from Krajbich, Armel, and Rangel (2010).

Due to its parsimonious approach and specific processing predictions, the aDDM has increasingly been applied to explain decision processes. Previous studies have shown that this model can provide a highly accurate quantitative account of the correlation between fixations and choices for binary and trinary choices (Krajbich et al., 2010; Krajbich, Lu, Camerer, &

Rangel, 2012; Krajbich & Rangel, 2011; Towal, Mormann, & Koch, 2013). Additional fMRI studies also lend support to the idea of the aDDM by showing that value signals computed in ventromedial prefrontal cortex at the time of choice, and widely thought to drive choices, are attentionally modulated (Lim, O'Doherty, & Rangel, 2011).

The ideas underlying the aDDM are closely related to the so-called *gaze cascade effect* as it also assigns eye gaze an active role in attractiveness preference formation (Shimojo, Simion, Shimojo, & Scheier, 2003). The probability of looking at the eventually chosen option increases as the point of decision comes closer – this is, it is assumed to “cascade” up until the decision point with a particularly strong correlation between fixations and choice in the last second prior to the decision being made. The gaze cascade effect has been successfully replicated in the same context (Bird, Lauwereyns, & Crawford, 2012), as well as in the domains of risky choices (Fiedler & Glöckner, 2012; Glöckner & Herbold, 2011), moral choices (Pärnamets et al., 2015), consumer choices (Atalay, Bodur, & Rasolofoarison, 2012), photographs (Glaholt & Reingold, 2009), and strategic choices (N. Stewart, Gächter, Noguchi, & Mullett, 2016).

Overall, by capturing the role of attention in decision making, these models indicate how behavior can be predicted more accurately by taking eye movements into account.

Measuring cognitive processes via eye-tracking

Self-reported measures have been extensively employed to study decision processes (e.g., think-aloud protocols). As the limitations associated with self-reports (e.g., due to social desirability) became more prevalent (e.g., Donaldson & Grant-Vallone, 2002), the need for a more unobtrusive measure to systematically investigate decision processes aroused. In this vein, *eye-tracking* represents a promising tool to gather process data on a fine-grained level. Eye-tracking devices allow researchers to record participants’ eye movements during their information uptake process. In other words, “eye movement research is beginning to take center stage as a means to trace the cognitive processes underlying judgments and decisions" (Ashby, Johnson, Krajbich, & Wedel, 2016, p. 2). First eye-tracking techniques were developed in the 1950s and required participants to wear contact lenses (Yarbus, 1967). Devices such as small mirrors and wires were attached to the lenses. Although this technology provided a sensitive measure of eye movements, limitations due to the invasive nature of wearing contact lenses were apparent. Current, non-invasive techniques of eye-tracking rely on video recordings of eye movements and continuously improve regarding their accuracy, usability and cost of acquisition. With the development of more user-friendly software, advancements of the hardware, and a decreased cost associated with the relevant technology, measuring eye movements is becoming more feasible to a larger number of researchers.

The human visual system can divided into three regions: foveal, parafoveal and peripheral (Rayner, 1998). The fovea is the central part of the retina that has the highest density of sensory neurons and therefore the greatest acuity. Visual acuity decreases in the parafoveal and is lowest in the periphery. The field of view is inspected through continuous brief eye movement, called saccades. This allows perceiving a stimulus through the fovea where acuity is very high. The time in between saccades when the eyes are relatively still are referred to as *fixations* that are about 200-300 ms long (Rayner, 1998). Previous research has shown that humans cannot obtain new information during saccades but only during fixations (Rayner, 1998) and therefore analysis of eye-tracking data in the present work focuses on fixations.

The eye-tracking system used in the following studies is based on the pupil-center/ corneal reflection method to determine eye gaze. This method captures voluntary, saccadic eye movements that fixate a target object on the fovea. An infrared-sensitive video camera, positioned below the computer monitor, observes the subject's eye and specialized image software generates x and y coordinates for the gaze point on the monitor screen. The corneal reflection of a light source is measured relative to the location of the pupil center (Duchowski, 2017). In order to distinguish between eye and head movements, two points of references on the eye are required – the pupil center and the corneal reflection. While the distance between the two points remains relatively stable with head movements, it changes with eye movements. Calibration procedures enable eye-tracking devices to identify these two points of reference and the corresponding gaze location on the computer screen.

Dependent measures of eye-tracking

Considering the wealth of data that is produced by measuring eye movements, it is especially important to define the dependent measures that are relevant to a specific question (for an extensive overview of eye-tracking measures see Holmqvist et al., 2011). While there are numerous measures that can be used, the following brief overview focuses on measures that were employed in the studies of this dissertation.

One of the most widely studied measures is the *position of a fixation*, which is essential for the interpretation of eye-tracking data (Meißner & Oll, 2017). The x and y coordinates provided by the technology reveal the position of a fixation on a computer screen. In order to facilitate interpretation of the data, researchers commonly define areas of interest (AOIs). AOIs can either be defined a priori through a software by physically drawing AOI boundaries around stimuli or by assigning fixations to AOIs post-hoc based on their coordinates (for a discussion see Orquin, Ashby, & Clarke, 2016). First recommendations on constructing AOIs include that they should be kept maximal to avoid false negatives (Holmqvist et al., 2011). On the other hand, large AOI margins (i.e. the buffer space around an object) increase the likelihood of false positives and overlapping AOIs. Orquin et al. (2016) recommend that AOI margins should only be maximal if the distance between objects is large. In case the distance is small and fixations even overlap, they argue that AOI margins should be smaller to balance the ratio of true and false positive fixations. Relying on the auxiliary assumption that what people fixate on is processed in that moment (eye-mind hypothesis; Just & Carpenter, 1976), the position of fixations is used to infer information processing in Chapter I, II and III.

Second, the *number of fixations* provides a valuable measure for how much attention individuals direct to specific stimuli (Meißner & Oll, 2017). Based on the assumption that fixation number and decision time indicate the depth of information search (Bettman, Johnson, Luce, & Payne, 1993), the number of fixations is used as an indicator for information search effort in Chapter I and II. To assess the number of fixations to an AOI in relation to the overall number of fixations, the *proportion of attention* is often computed. The proportion of attention is used to quantify the relative importance or weight of the contained piece of information as more important pieces of information are fixated more often (e.g., Russo & Leclerc, 1994). Therefore, the proportion of attention is used as an indicator for information weighting in Chapter I and II.

Third, eye-tracking devices record the *fixation duration*. It quantifies how long an individual's eyes are in one position and indicates the duration of a fixation. The sum of fixation duration is usually interpreted as an indicator of the processing depth or effort (Russo, 2011). Depending on the stimuli that are fixated and their features, fixation duration usually ranges from 100 to 500 ms (Rayner, 1998). As it is argued that individuals need to fixate information for at least 200 ms in order to process it (Rayner, 1998), fixations shorter than 200 ms are generally not subject to data analyses if deliberative processes are studied. Further, fixation duration changes depending on how much time has passed in the decision process (Glöckner & Herbold, 2011; Krajbich et al., 2012).

Fourth, *temporal dynamics* of visual attention offer valuable insights into the decision process. Through temporal dynamics of eye gaze researchers gain a deeper understanding of what information is relevant to the decision maker at which point in time. In particular, first and last fixations offer important insights into the decision process. Information that is encoded at the beginning of the decision process is more likely to be remembered (Murdock

Jr, 1962) and has a stronger influence on the valuation of goods (Johnson, Haubl, & Keinan, 2007). In risky choices, options that are fixated first are more likely to be chosen subsequently (Manohar & Husain, 2013). Similarly, last fixations are especially relevant as they are a stronger predictor of choices than previous fixations (Fiedler & Glöckner, 2012; Krajbich et al., 2010). The role of last fixations is further highlighted in theoretical assumptions of the aDDM and the gaze-cascade effect. Here, it is argued that subjects generally choose the option they looked at last.

In sum, eye-tracking makes it possible to capture the location, duration and proportion of attention, as well as its changes over time. Therein, eye-tracking offers a fine-grained measure of attention, which provides a valuable tool to uncover underlying drivers of decision making.

Top-down and bottom-up shifts of attention

Traditional models of decision making such as models of rationality and bounded rationality (H. A. Simon, 1972) assign a passive role to attention in the decision making process. Specifically, the models assume that attention serves the decision makers by passively acquiring necessary information (*top-down*). More recently, frameworks such as drift-diffusion models and the gaze cascade effect have proposed that attention has a more active role in constructing the decision (*bottom-up*) (Krajbich et al., 2010; Shimojo et al., 2003). The distinction assumes that orienting of attention during information search depends on the goal an individual has in mind (for an overview see Orquin & Mueller Loose, 2013). It is important to note here that the two approaches are not necessarily mutually exclusive and both bear significantly on contemporary concepts of visual attention (Duchowski, 2017). Rather than adopting a dichotomous view to explain visual attention, this research focuses on identifying the respective magnitude of each channel.

Top-down control of visual attention is commonly defined as goal-driven. In a seminal work on top-down attention by Yarbus (1967), participants viewed photographs with different goals in mind and exhibited different patterns of eye movements. This work highlights the contingency of task relevance on the demands of a task. The perceived task relevance can be affected by a number of factors that were discussed in detail by Orquin and Mueller Loose (2013). These factors include task instructions, utility effects (i.e., people tend to gaze at information with greater utility), manipulating the use of heuristics (mostly by training participants to employ specific heuristics), attention phases (i.e., eye gaze patterns depend on the phase of the decision process until a choice is made), and learning effects. Thus, goal-driven top-down processes have an impact on subsequent choices people make.

On the other hand, bottom-up processes were defined as stimulus-driven control of visual attention. The surrounding context and topographical encoding of stimuli affect saliency-driven attention and was incorporated in a computational model of visual attention (Itti & Koch, 2001). For instance, results mainly from research on consumer decision making indicate that individuals are more likely to choose food items that are visually salient due to special fonts (Armel et al., 2008; Milosavljevic, Navalpakkam, Koch, & Rangel, 2012) or position (Reutskaja, Nagel, Camerer, & Rangel, 2011).

Within Chapter III of this dissertation, top-down and bottom-up shifts of attention are studied in more detail, especially in the context of (other-regarding) social preference and moral choices. Whereas most research discusses social preferences as a stable construct (Carlsson, Johansson-Stenman, & Nam, 2014) that strongly influences other-regarding choice behavior (Balliet et al., 2009), increasing evidence indicates that choices in the social domain can be influenced by subtle manipulations of bottom-up features such as changes in the set of options (Knez & Camerer, 1995) and visual cues (Haley & Fessler, 2005). Corroborating evidence has also been brought forward in the domain of moral decision making. Here, initial judgments of an action being right or wrong are claimed to be formed through bottom-up processes of moral reasoning (Bargh & Chartrand, 1999). Even slight changes in the representation such as the presentation order of a set of moral problems appear to influence the way decisions are made (Iliev et al., 2009).

Overall, these findings indicate that choices are driven by a two-channel mechanism that includes top-down and bottom-up processes. The studies presented in Chapter III aim to disentangle the impact of top-down preferences and characteristics of choice presentation by using eye gaze as an indicator of other-regarding and moral choice processes.

Social dilemmas in academia: The replication crisis

> “In so far as a scientific statement speaks about reality, it must be falsifiable; and in so far as it is not falsifiable, it does not speak about reality.“ (Popper, 2005, p. 316)

Replication is a cornerstone of science. In order to lead a fruitful scientific discourse, evidence needs to be falsifiable (Popper, 2005) and researchers should aim for their findings to be reproducible, robust and generalizable. Reproducibility describes the extent to which consistent results are observed when scientific studies are repeated (Open Science Collaboration, 2012). Yet, replications are not (yet) a notable part of scientific practice. While researchers gain prestige and reputation for novel research, conducting a replication study does not offer any comparable advantages (Nosek, Spies, & Motyl, 2012). Due to such incentive structures, replications are underrepresented in published articles and false positive results remain unchallenged (Nosek et al., 2012).

The so-called “replication crisis” describes a recent decrease of confidence in scientific findings due to lack of successful replications. In the early 2010s, questionable research practices were identified to be common in psychology (John, Loewenstein, & Prelec, 2012). While questionable research practices (e.g. failing to report all dependent measures) are not identical to fraud, they affect the quality of published research substantially. It was argued that incentive structures that favor confirming evidence over null results promote such fraudulent behaviors (Nosek et al., 2012). The replication crisis has been interpreted as a social dilemma, which especially affects early-career researchers (Everett & Earp, 2015). While it is in everyone’s interest that studies are replicated to verify their scientific value, it is not in the self-interest of an individual researcher to conduct this replication. A possible solution the authors propose to solve the dilemma is to include replications as mandatory components of PhD programs.

Another approach is proposed by the Open Science movement, which distributes the cost of conducting a replication across a large number of researchers by promoting large-scale collaborations. Aiming to solve the paradox between incentive structures and the importance of falsification in science, the Open Science movement set out to change the incentive structures in the publication system. The Reproducibility Project is one of the first large-scale collaborations that systematically estimated the reproducibility rate of psychological science and investigated factors predicting reproducibility (Open Science Collaboration, 2015). In total, 270 contributing authors completed 100 replications by closely following a protocol for conducting high-quality replications. While 97% of the original studies had statistically significant results, only 36% of the replications had statistically significant results.

Their approach focuses on the overall reproducibility rate rather than individual studies' replicability after multiple replication attempts (Open Science Collaboration, 2012). There has been disagreement regarding the interpretation of replications– what does it mean if a replication failed and what can we conclude from successful replications (Earp & Trafimow, 2015)? Not finding the same results as an original study can have more than one reason. Even if the replication was conducted as careful as possible using original materials, there is chance for a Type II error of 1–β of not finding a true effect. On the other hand, failures to replicate include that the original study suffered from a Type I error, finding an effect when there is no true effect. Other reasons for failed replications include insufficient power and methodological flaws in either the original or the replication. Earp and Trafimow (2015) argue that to achieve the most informative value, a series of replications should be conducted independently across different labs. Examples for such large-scale replication efforts include the Many Labs replications projects (R. A. Klein et al., 2014) and Registered Replication

Reports (e.g., Bouwmeester et al., 2017). Here, the influence of time pressure on cooperation was replicated across 21 independent, pre-registered studies.

In order to further improve scientific research methodology, Open Science proposed a number of practices for authors as well as editors to ensure the publication of high-quality research. These include publication of studies independent of their statistical significance (e.g., Nosek & Lakens, 2014), the publication of replication studies (e.g., Koole & Lakens, 2012), pre-registration of hypotheses and methods, transparent analyses (Bakker, van Dijk, & Wicherts, 2012) and free availability of the raw data (Wicherts, Borsboom, Kats, & Molenaar, 2006). Rather than being a constraint, it was argued by Frankenhuis and Nettle (in press) that these practices have a liberating component because they offer the possibility to explore data transparently, a reward for quality that can be influenced rather than outcomes which can not be influenced, and a reduction of the need to find positive results.

In sum, psychological science has recently made improvements to the quality of their research by identifying unreliable effects, acknowledging the importance of and creating incentives for replication studies and formulating recommendations for open and transparent research practices. All studies included in this dissertation followed these recommended practices by making all materials and data openly available. In addition, the hypotheses for studies in Chapter I and III were pre-registered prior to data collection.

The present research

This works aims to provide a bridge between the fields of behavioral economics and psychology. It offers insights on cognitive processes underlying decision making from an individual differences perspective. The SVO framework offers an excellent theoretical framework to address questions raised regarding individual differences– social preferences in particular. Going beyond choice behavior, the eye-tracking methodology offers a novel perspective on attentional cognitive processes underlying choices in social dilemmas. In this thesis, I use both approaches: Chapter I addresses the link between social preferences (measured through SVO) and recall of an interaction partner's cooperation behavior, with contributions to the understanding of memory lack as a possible reason for systematic deviations from cooperation. Focusing on attention patterns in more detail, Chapter II studies how social preferences affect information search effort and weighting in strategic social interactions. It contributes to understanding the individual motivations and considerations that drive strategic decision making. Chapter III investigates the link between top-down and bottom-up processes of attention on other-regarding choices, with contributions to understanding how decisions can potentially be influenced by guiding attention or systematic interruptions of the decision process.

Chapter I: The cost of imperfect memory in social interactions

Chapter I builds upon the ability to sustain cooperation between unrelated members of a group – one of the hallmarks of human behavior and suggested to be a driving force in the evolution of human intelligence (e.g. McNally, Brown, & Jackson, 2012). Reciprocity, however, requires keeping track of the interaction partner's behaviors, which can be a taxing task with growing social environments. As a solution, social contract theory has proposed that people possess a so-called cheater module, i.e. a heightened ability to remember people that cheated on them – which protects cooperative individuals from being exploited (Cosmides &

Tooby, 1989). However, although some studies have found support for a cheater module (Chiappe et al., 2004; Mealey et al., 1996; Yamagishi et al., 2003), the ability to remember some people better than others does not appear to be specific to cheaters (Barclay & Lalumière, 2006; Buchner et al., 2009; Volstorf et al., 2011). From an evolutionary perspective, the ability to remember an interaction partner's behavior and avoid exploitation should be particularly important for prosocial individuals. Thus, Chapter I addresses whether memory benefits may not only be a function of the interaction partners' behavior but also depend on the prosocial orientation of the individual. Within three pre-registered studies, Chapter I investigates whether the ability to remember how a social interaction partner behaved is related to an individual's social preference. A second goal of Chapter I is to identify potential drivers of the effect by analyzing information search during encoding of the partners' behavior.

Chapter II: Social Value Orientation predicts information search in strategic settings: An eye-tracking analysis

Chapter II focuses on attention patterns in strategic choices and thereby extends research on the underlying cognitive mechanisms in social dilemmas. Previous studies investigating beliefs and expectations within strategic interactions provided first indications for a heterogeneity that extends from choices to the mental representation of these situations (Smeesters, Warlop, Van Avermaet, Corneille, & Yzerbyt, 2003; Van Lange, 1992). Yet, an understanding of the underlying motivational mechanisms of strategic social decision making is largely lacking. In Chapter II, the goal is to shed light on the cognitive channels linking social preferences and cooperation behavior. To pursue this objective, we systematically examine whether information search effort and weighting are driven by social preferences when people contemplate strategic decisions. Specifically, this work examines the impact of SVO on information search in a simple symmetric prisoner's dilemma. In addition to individual differences, Chapter II aims to uncover whether the relation between attention and other-regarding choices goes beyond a correlational link. In order to particularly capture the temporal dynamics of strategic decision making, a process measure approach utilizing eye-tracking is employed. Particularly, the research examines how contextual variation influences people's choices in a prisoner's dilemma.

Chapter III: The power of attention: Using eye gaze to predict other-regarding and moral choices

Chapter III of this dissertation builds upon a number of studies that have used gaze recordings to understand the processes underlying decision making in different areas (for a review see Orquin & Mueller Loose, 2013). So far, they have provided consistent evidence for a correlation between eye gaze and subsequent other-regarding (e.g., Fiedler et al., 2013) and moral choices (Pärnamets et al., 2015). The current state of the evidence suggests that both top-down preferences and characteristics of choice presentation drive information search. Inspired by these findings, Chapter III aims to disentangle these two drivers of the correlation between eye gaze and choice behavior. In doing so, we critically tested the causality claims made in recent publications (Armel et al., 2008; Milosavljevic et al., 2012; Newell & Le Pelley, 2018; Pärnamets et al., 2015) in two high-powered, eye-tracking studies using eye gaze to predict other-regarding and moral choices. Study 1 focuses on three key points: First, we aim to disentangle top-down and bottom-up processes of decision making. Second, we will test whether the effect of attention on choices is context-dependent by comparing other-regarding and moral choices. Due to selection biases that were identified in the data, Study 2 utilizes a decision paradigm that allows to fully control information intake to test for the influence of attention on choice. This design enables us to partial out bottom-up processes of attention on choices more clearly and avoids potential selection effects.

Chapter I

The cost of imperfect memory in social interactions

Minou Ghaffari [a, b] Susann Fiedler [a], & Bettina von Helversen [b]

[a] Max Planck Institute for Research on Collective Goods, Bonn

[b] University of Zurich

This article was submitted for publication to the *Journal of Personality and Social Psychology*.

Abstract

Memory has been proposed as one of the most crucial cognitive capacities required for successful cooperation in social dilemmas. Remembering whether a person cooperated or defected in a previous interaction enables decision makers to avoid being exploited by free riders. From an evolutionary perspective, the ability to remember an interaction partner's behavior and avoid exploitation should be particularly important for prosocial individuals. Following this idea, we investigated whether the ability to remember how a social interaction partner behaved is related to an individual's social preference in three studies. Further, we aimed to identify potential drivers of the effect by analyzing information search during encoding of the partner's behavior. Using eye-tracking, we recorded participants' gaze behavior during the observation of other players' previous choices in decomposed games. Subsequently, participants were asked to recall the behavior of each observed player. We then used individuals' social preferences (measured as social value orientation) to predict participants' memory performance. We found that prosocial individuals were more likely to recall previous players' behavior than proself individuals. Moreover, a mediation analysis indicated that those differences were partly driven by the extent of information search during encoding. In sum our results suggest that prosocial individuals are better able to identify free riders, which could protect them from being exploited in future interactions.

Keywords: Memory, social preferences, cognitive processes, attention

Introduction

The ability to sustain cooperation between unrelated members of a group is one of the hallmarks of human behavior and is suggested to be a driving force in the evolution of human intelligence (e.g., McNally et al., 2012). A cornerstone of the evolution of cooperative behavior is reciprocity (Trivers, 1971). Purely cooperative and prosocial behavioral strategies fail to succeed, because they pose a disadvantage if they are not reciprocated. In contrast, strategies that show reciprocal cooperation such as the famous “tit-for-tat” strategy thrive because they enable individuals to profit from the mutual benefits of cooperation while protecting them from being exploited by selfish individuals (Axelrod & Hamilton, 1981). Reciprocity, however, requires keeping track of the interaction partner’s behaviors, which can be a taxing task with growing social environments. As a solution, social contract theory has proposed that people possess a so-called cheater module, i.e., a heightened ability to remember people that cheated on them – which protects cooperative individuals from being exploited (Cosmides & Tooby, 1989). However, although some studies have found support for a cheater module (Chiappe et al., 2004; Mealey et al., 1996; Yamagishi et al., 2003), the ability to remember some people better than others does not appear to be specific to cheaters (Barclay & Lalumière, 2006; Buchner et al., 2009; Volstorf et al., 2011). Moreover, it is still unclear whether the reported memory benefits are sufficient to sustain cooperation (Stevens, Volstorf, Schooler, & Rieskamp, 2011). Thus, we suggest that memory benefits may not only be a function of the interaction partners’ behavior but also depend on the prosocial orientation of the individual. Individuals show stable differences in their social value orientation (SVO), a measure that differentiates between individuals who typically cooperate and individuals who primarily attempt to maximize their own payoff (Liebrand & McClintock, 1988). Cooperative individuals are not only more likely to make prosocial choices, they also show more interest in their interaction partner’s payoff (Fiedler, Glöckner, Nicklisch & Dickert, 2013). This suggests that cooperative individuals will have a better memory for their interaction partner and their behavior, enabling them to protect themselves from being exploited.

In the following, we will first review the literature on memory, cooperation, social preferences, and attention to interaction partners and explain our hypotheses in more detail. Then, we will report three empirical studies we conducted to test the hypotheses.

Cooperation, reciprocity, and memory

Cooperation is defined as the process of groups or individuals working together for common or mutual benefit. However, cooperation is susceptible to exploitation and free-riding, making it difficult for purely cooperative strategies to prevail (Fischbacher, Gächter, & Fehr, 2001). Cooperative strategies, however, are successful when cooperation is reciprocal – that is, cooperation is only maintained when the interaction partner also cooperates. Reciprocity, for instance, has been identified as a crucial mechanism for mutual cooperation to develop in societies (Trivers, 1971). However, reciprocity is only possible when interaction partners can track each other's behavior (Cosmides & Tooby, 1989). In many interactions, reciprocity is delayed rather than simultaneous. This time delay requires memory capacity in order to recall an individual's previous behavior. For example, if there is a lengthy timespan between two group projects, one must be able to recall a coworker's cooperation behavior in the first project in order to reciprocate in the next project. Furthermore, memory enables us to predict future behavior (Atance & O'Neill, 2001). Thus, knowing that someone returned a favor in the past will increase the likelihood of initiating prosocial behavior in a new interaction, which represents the first step in building a relationship based on reciprocity.

According to the social exchange theory, cognitive capacities associated with memory for individuals who cheated or hurt us should be favored by natural selection so they can be avoided in the future (Cosmides & Tooby, 1989). Several studies have investigated this proposition and revealed inconsistent evidence. Although some studies found that faces of defectors were recognized more quickly and remembered better than faces of cooperators (Mealey et al., 1996; Verplaetse, Vanneste, & Braeckman, 2007; Yamagishi et al., 2003), a number of studies failed to replicate evidence for preferential face recognition of defectors (Barclay & Lalumière, 2006; Buchner et al., 2009; Mehl & Buchner, 2008). Based on this evidence, Buchner et al. (2009) argued that instead of face recognition, memory for the behavior associated with a face is the more relevant aspect. Focusing on memory for behavior instead of mere face recognition, they found that recalling whether a person had defected was consistently better for faces associated with defection than for faces associated with cooperation. However, other studies showed that the observed memory improvements are not specific to remembering whether someone defected but are instead driven by more general mechanisms that influence memory such as the strength of the emotional reaction and expectance incongruity (for an overview, see Bell & Buchner, 2012). Similarly, Bell and Buchner (2011) showed that when describing trustworthy behavior with a high valence strength and cheating behavior with a low valence strength, the memory advantage for cheaters disappeared. Likewise, varying the frequency of how often cheating and cooperative partners were encountered suggested that rarely encountered partners are remembered better (Volstorf et al., 2011).

Overall, there is little evidence for a cheater module. However, source memory for cheating or defection behaviors can be better than for cooperative behaviors, especially if cheating is rare and of high negative valence. Nevertheless, studies attempting to simulate the level of memory necessary to sustain cooperation indicated that average levels of memory performance typically found in laboratory experiments may not suffice (Stevens et al., 2011), suggesting that further mechanisms may be necessary to understand how cooperation can be maintained.

Social preferences and cooperation

While most people are sometimes prosocial and sometimes behave selfishly, there are stable individual differences in people's social preferences. Specifically, it has been suggested that individuals differ in terms of the degree to which they only care about resources allocated to themselves (self-interest) or also care about resources allocated to others (Fehr & Fischbacher, 2002). One construct measuring these individual differences is the concept of SVO (Liebrand & McClintock, 1988). SVO refers to how people approach social dilemmas, that is, social interactions in which one's own benefits are weighed against consequences for others (Cox et al., 1999; A. J. Stewart & Plotkin, 2016; Van Lange, 1999). Depending on their SVO, people vary in terms of the weight they attach to the outcomes they receive themselves and the outcomes allocated to other people. In terms of utility, the concept of SVO assumes that individuals gain utility not only from their own payoffs (p_{own}) but also from other's payoffs (p_{other}). This assumption is formally expressed in the following utility function (Liebrand & McClintock, 1988):

$$U = w_1 \times u(p_{own}) + w_2 \times u(p_{other})$$

where u indicates a utility transformation function of outcomes and w indicates the weights assigned to one's own outcomes (w_1) and other's outcomes (w_2). An individual's SVO is represented by an SVO angle, which is a continuous measure computed using the weights assigned to one's own and other's outcomes. An SVO angle is constructed using the radian value of the arccosine of the sum of payoffs allocated either to oneself (p_{own}) or the other person (p_{other}) and is computed as follows.

If the sum of the other's payoffs is positive:

$$SVO\ angle = \cos^{-1}\left(\frac{\sum p_{own}}{(\sum {p_{own}}^2 + \sum {p_{other}}^2\ )^{0.5}}\right) \times \frac{180}{\pi}$$

If the sum of other's payoffs is negative:

$$SVO\ angle = -\cos^{-1}\left(\frac{\sum p_{own}}{(\sum p_{own}{}^{2} + \sum p_{other}{}^{2})^{0.5}}\right) \times \frac{180}{\pi}$$

Based on the SVO measure, four types of people are typically differentiated: *Altruists*, who only value the other's outcome; *cooperators*, who assign equal weight to their own and the other's outcomes; *individualists*, only assign weight to their own outcome; and *competitors*, who value their own outcomes as well as comparatively smaller gains for the other (Liebrand & McClintock, 1988; McClintock, 1972). However, these four types are frequently grouped into two categories: *prosocials* (altruists and cooperators) and *proselfs* (individualists and competitors). Typically, individuals' preferences fall between these two extreme types in that they weight their own payoffs higher than the other's payoff but do not ignore the latter completely.

SVO has been shown to be related to individual differences in concepts associated with a range of prosocial behaviors such as empathy and perspective-taking (Declerck & Bogaert, 2008), beliefs about others (Kelley & Stahelski, 1970), fairness concerns (De Cremer et al., 2005), and a sense of social responsibility (De Cremer & Van Lange, 2001). Furthermore, studies using social dilemmas, have found that individuals with a more prosocial SVO are more likely to cooperate in both, laboratory and field settings (for overviews, see Balliet et al., 2009; Bogaert et al., 2008).

These results suggest that the ability to remember an interaction partner's behaviors may be particularly important for prosocial individuals. Prosocial individuals are more likely to cooperate and thus also risk being exploited by selfish interaction partners. However, if they are able to remember their interactions partner's behavior, this would allow them to avoid individuals who do not reciprocate, and still maintain cooperation with other prosocial individuals. First evidence of this link stems from literature on individual differences in prosocial behavior as well as how they relate to processing information about other people.

SVO, attention, and memory

Prosocial and proself individuals differ not only in terms of how much they cooperate in social dilemmas but also regarding the cognitive processes underlying their decision process (Jiang, Potters, & Funaki, 2016). This suggests that prosocials pay more attention to their interaction partners. Prosocials took longer to make a decision in social dilemmas (Dehue, McClintock, & Liebrand, 1993) and were more likely to seek information supporting cooperative behavior than proself individuals (Camac, 1992). Furthermore, in a money allocation task, prosocial individuals inspected more information and directed more attention to the other player's payoff as compared to proself individuals (Fiedler et al., 2013).

This increase in attention suggests that prosocial individuals should also have a better memory of the task structure and their interaction partners' behavior. Researchers have noted that attention and memory appear to be adaptively tuned such that individuals focus on and remember key features of the environment that have been closely linked to differential reproductive success over evolutionary time (Buss, 1989; S. B. Klein, Cosmides, Tooby, & Chance, 2002; Maner, Gailliot, Rouby, & Miller, 2007; McArthur & Baron, 1983; Nairne, Pandeirada, Gregory, & Van Arsdall, 2009; Schützwohl, 2006; Schützwohl & Koch, 2004). Memory abilities are related to attention during encoding. Attending to a fact or event enhances the likelihood of later memory (Chun & Turk-Browne, 2007). For instance, several studies have found that the number of fixations directed to a stimulus are predictive of subsequent memory performance (Bloom & Mudd, 1991; Kafkas & Montaldi, 2011). Exposure time to a face successfully predicts identification accuracy (Bornstein, Deffenbacher, Penrod, & McGorty, 2012; Laughery, Alexander, & Lane, 1971). In turn, the ability to remember an interaction partner's behavior should enable prosocial individuals to pick interaction partners who will cooperate with a higher likelihood than proself individuals, thus reducing the risk of being exploited by selfish interaction partners.

An additional factor that is related to the fear of being exploited by selfish individuals is risk aversion. A recent study found that risk-averse individuals were more likely to cooperate with their partners than risk-seeking individuals in cooperation-friendly environments, where the risk of being cheated on was low, but not in cooperation-unfriendly environments (Glöckner & Hilbig, 2012). On a process level, more risk-averse individuals exhibited more extensive information search in consumer decisions (Conchar, Zinkhan, Peters, & Olavarrieta, 2004). This pattern of decision behavior and processes is similar to the patterns observed for prosocial individuals in social dilemmas. To avoid confounding risk aversion with prosociality when predicting memory performance, risk aversion is included as a control variable in the studies.

To test our hypotheses, we conducted three studies investigating the relationship between social preferences and memory by studying recall of an interaction partner's behavior in a social dilemma. Study 1 was an online investigation examining the premise that an individual's social preferences, their SVO in particular, are linked to memory performance when recalling an interaction partner's behavior. Going one step further, in Study 2a we then used eye-tracking to assess the underlying processes that potentially drive the effect between memory and social preferences. Specifically, we examined how much of the relationship between SVO and memory can be attributed to orienting attention during information encoding. Exploring boundary conditions of this relationship, Study 2b then investigated the link between SVO and long-term memory for interaction partners. Finally, in Study 3 we again conducted an online study investigating whether memory for interaction partners' behavior enables prosocial individuals to select interaction partners who are more likely to be cooperative than proself individuals.

Study 1

Study 1 is an online study that aimed to assess the relation between SVO and explicit memory. Participants repeatedly interacted with others and allocated money between themselves and the interaction partner. In each trial, they received feedback on their interaction partner's behavior. After working on a distractor task, participants were asked to recall their interaction partner's behavior. Based on theory and previous findings, we assume that individuals who are more prosocial are more likely to correctly recall their interaction partner's behavior than individuals who are less prosocial (H1). Memory is measured by explicitly asking participants to recall their interaction partner's behavior. We are also interested in the drivers of this relationship and hypothesize that encoding depth in the initial encoding phase will be one of the main factors that influence the recall probability. Specifically, we hypothesize that individuals who are more prosocial exhibit longer search times when encoding their interaction partners behavior as well as longer response times for their own choice (H2). Investigating the role of information search more closely, we assume that response time partially mediates the link between SVO and explicit memory (H3).

Method

Participants. Seventy-nine participants from the Max Planck Decision Lab subject pool (students of the University of Bonn) were recruited via Orsee (Greiner, 2015). The experiment was conducted online via the platform *Unipark* and lasted approximately 40 minutes. Participants were fully incentivized and received a mean payoff of 9.20 Euros (≈ 11.30 USD), which varied according to their choices. The pre-registered number of participants who were scheduled to take part in the study was set to 66 to account for dropouts. Due to a technical error (n = 13), an additional 13 participants were scheduled for participation. Participants with incomplete data (n = 5) were excluded, resulting in a final sample of 61 participants (mean age = 23.1 years, 75.4% female). We determined the target sample size of at least 60 participants by conducting an a priori power analysis (power = .80) based on an effect size estimate retrieved from a re-analysis of data collected by Volstorf et al. (2011). For a more detailed description of the power analysis as well as the pre-registered hypotheses and analyses, see bit.do/Preregistration_Study1. Following the literature, we refer to altruists and cooperators as prosocials (SVO angle > 22.5°) and individualists and competitors as proselfs (SVO angle < 22.5°).[1]

Materials.

Money allocation task. Participants encountered 10 money allocation problems in the main part of the experiment. In each problem, participants are asked to decide between two payoff combinations, labeled as option A and B. The two options differed regarding the possible payoffs for the participant and their matched interaction partner (see Figure 2). For each of the 10 pairs, participants were instructed to choose the outcome distribution they most preferred. We constructed the 10 money allocation problems in two steps. First, using data from a previous study run at the Max Planck Decision Lab, we identified items of the SVO ring measure (Liebrand & McClintock, 1988) that were particularly high in their diagnostic value and clearly distinguished between prosocial and proself players. Second, based on these items, we constructed new problems that had similar cost-benefit ratios but varied in their payoffs.[2]

Face stimuli. To represent the interaction partners, participants were shown pictures of 5 females and 5 males between 19 and 30 years old displaying a neutral facial expression. These pictures were taken from the FACES Database (Ebner & Johnson, 2010; see Figure 2 for an example). The 10 faces were all rated as moderately attractive (M = 2.09, SD = 0.05, range of the rating scale: (1) very unattractive – (4) very attractive).[3]

[1] For a graphical representation of the distribution of SVO angles for all studies, please see Figure S1 in the supplementary material provided online.
[2] A list of money allocation tasks used for all studies is provided in the online supplementary material (Table S1).
[3] We selected the 10 faces by using data from a previous study in which the attractiveness of the same pictures

SVO ring measure. Participants completed the SVO ring measure in the fourth part of the online study. The instrument is frequently used to determine individual social preferences, i.e. weighting of one's own and others payoffs. Specifically, participants were asked to make 24 choices between two options representing money allocations that differed in terms of payoffs for one's self and others. Participants could either maximize their own payoff or decide to forego money in order to benefit the other. According to their choices, participants were classified as prosocial (SVO angle > 22.5°) or proself (SVO angle < 22.5°). The mean SVO angle was 22.54° (SD = 20.37°). 29 participants were classified as prosocials; and 32 as proselfs. Participants' choices were fully incentivized such that one of the money allocations was randomly selected and paid out at the end of the study.

Risk aversion. As a control variable, participants completed a test for risk aversion (Holt & Laury, 2002). The test consists of 10 choices between two options with varying probabilities of receiving a certain payoff. One of the options is always safe and the other always risky to varying degrees. The probability of the high-payoff risky outcome gradually increases with the riskier option becoming progressively less risky from item 1 to item 10. The point at which participants switch to the risky option is used as an indicator for their risk aversion, where later switches indicate greater risk aversion. A relative risk aversion parameter was calculated for every participant based on the procedure described by Holt and Laury (2002).

A complete overview of the items, face stimuli, original instructions, and a print version of the experiment can be found here bit.do/Materials_Study1.

Procedure.

Encoding phase. In the first part of the experiment, participants repeatedly engaged in a money allocation problem with 10 different interaction partners.

---

was rated on the same scale (Hayn-Leichsenring, Kloth, Schweinberger, & Redies, 2013).

In each interaction, participants first observed the decision their interaction partner had made in the respective money allocation problem (*partner's decision*). After observing the interaction partners' choice, the participant made a choice regarding the same money allocation task and the same partner (*own decision)*. In each interaction, participants viewed a face representing the interaction partner, the money allocation problem, and the partner's choice. The interaction partner's choice was either individualistic (i.e. maximizing the payoff of the interaction partner) or prosocial (i.e. maximizing the payoff of the participant). Each partner was represented by the same face picture in all interactions. However, participants were informed that the presented face did not display the actual participant but rather was used as a place holder representing the respective person. The option that was chosen by their partner in the money allocation problem was visually highlighted using a dark grey rectangle as a background (see Figure 2). To avoid confounding faces and type of players (individualistic vs. prosocial) each face had the same likelihood of being presented with a prosocial or an individualistic player (between subjects). Further, we counterbalanced all tasks concerning the position of the prosocial option in the matrix (left or right).

Participants interacted with each of the 10 partners 7 times, resulting in a total of 70 choices (i.e., 7 blocks). The presentation order was randomly determined within a block. Participants responded to five players who had chosen the prosocial option and five players who had chosen the individualistic option. Each partner was always shown together with the same money allocation problem; participants were informed that because the other player received no feedback, the option chosen by the partner would be constant across the seven blocks.

To incentivize choices, participants were informed that one of the rounds would be selected at random and paid out at the end of the experiment. The payout was determined after all participants had completed the task. Participants were matched in pairs, depending on the behavior they had observed in the selected round, as well as on their own choice, such that the matched partner's choice corresponded to the observed behavior. After completing the seven blocks, a short distractor task followed, asking participants to memorize the order of symbols and then sort them correctly.

Explicit memory phase. In the subsequent explicit memory phase, participants were asked to recall how their interaction partners behaved during the encoding phase. Again, the interaction partners and the respective money allocation problems were presented in random order. Participants could indicate whether the player had chosen option A or option B by pressing on the corresponding button. This task was fully incentivized in that participants could earn an extra 10 cents for each correct answer. After completing the task, participants received feedback regarding their number of correct answers.

After the experiment ended, participants were asked to complete the SVO ring measure and, finally, the risk aversion measure.[4]

Data analysis. To test whether social preferences have an impact on memory for interaction partners' behavior, we used a repeated measurement logistic regression predicting memory accuracy by SVO angle. Analyzing the influence of SVO angle on response time, we used a repeated measures linear regression. Prior to analyses, we tested the assumption of a normal distribution of response time using the Shapiro-Wilk test. The results indicate a skewed distribution ($W = 0.63$, $z = 12.15$, $p < .001$). We corrected for this by log-transforming response time. Using a mediation analysis, we then tested whether the effect of SVO angle on memory accuracy is mediated by response times. When entering interaction effects, we centered all involved predictor variables. For all regression analyses, we calculated robust standard errors. Throughout the article, we report two-sided test statistics. We use a significance level of $\alpha = .05$ when testing undirected hypotheses and a significance level of $\alpha = .10$ when testing directed (and preregistered) hypotheses for interpretation purposes. In order to test the stability of the result, we controlled for participant gender, the interaction

[4] Participants additionally rated the attractiveness of the presented faces for another unrelated project after completing this study.

partner gender, risk aversion, the cost-benefit ratio of the item, the pre-rated attractiveness of the face, as well as the observed behavior (prosocial vs. individualistic choice) to predict memory accuracy and information search. These factors have been identified in the literature as potential drivers of memorability. The raw data are available here bit.do/Data_Study1; and a detailed description of all analyses here bit.do/Analysis_Study1.

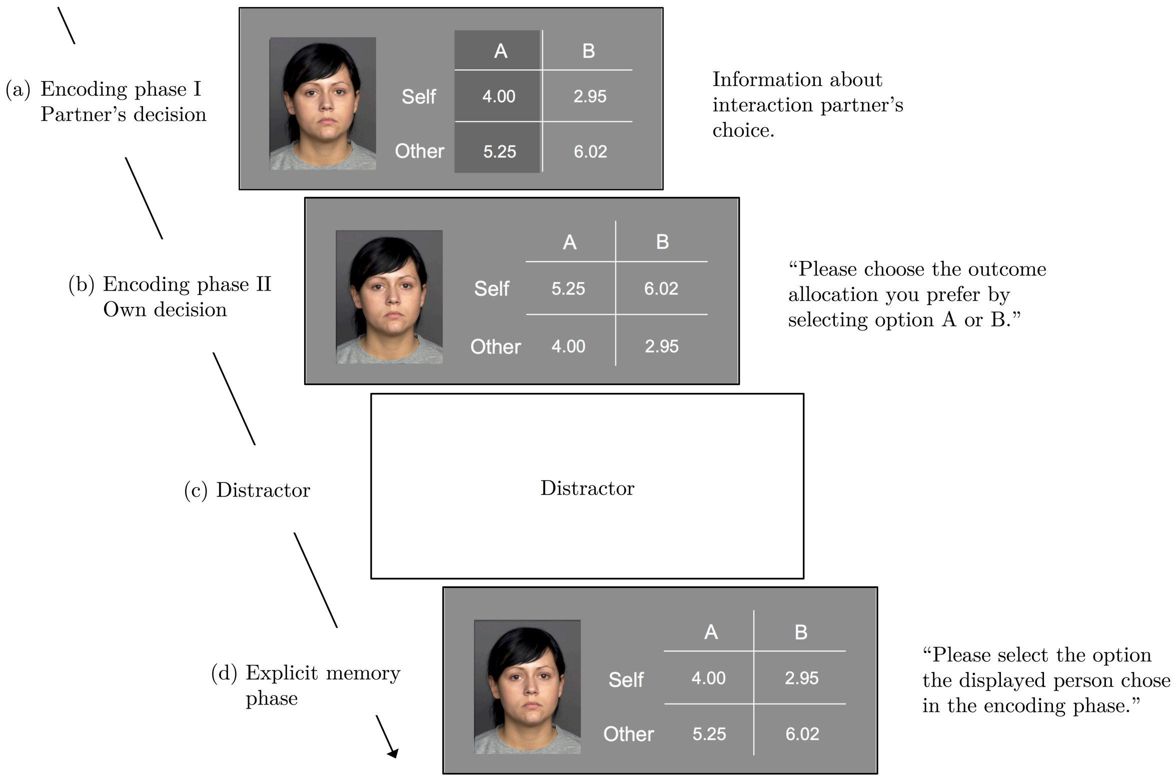

Figure 2. Experimental procedure of Study 1. (a) Partner's decision: Observation of interaction partner's choice. In this example, the partner chose option A. (b) Own decision: The participant could choose how to distribute money between himself and the displayed partner by choosing either option A or B. (c) Distractor: Presentation of distractor task. (d) Explicit memory phase: Recalling the displayed person's behavior.

Results

Predicting explicit memory performance. Overall, participants recalled their interaction partner's behavior in 74.26% of trials. The correct explicit memory rate was 80% for prosocial participants and 69.06% for proself participants. To test our first pre-registered hypothesis, namely that more prosocial individuals are more likely to correctly recall their interaction partner's behavior than less prosocial individuals (H1), we predicted the correct recall of an interaction partner's behavior using SVO angle. The results show that individuals with a higher SVO angle (more prosocial) exhibit better recall of their interaction partners' behavior in a social dilemma ($\beta = .31$, $z = 2.43$, $p = .015$, see Figure 3a). Descriptively, the proportion of correctly recalled types of behavior was 10.94 percentage points higher for participants classified as prosocial than for those classified as proselfs (Cohen's $h = .25$).[5] Controlling for the variables identified above, the results indicate that the effect of SVO on explicit memory performance persists (see Table S3). The results reveal no significant effect of interaction partner's type on explicit memory ($\beta = -.11$, $z = -0.86$, $p = .389$). In line with previous findings, SVO angle successfully predicted the proportion of prosocial choices in money allocation tasks while controlling for the same factors as above (see Table S4).

[5] $h = 2\sin^{-1}\sqrt{P_1} - 2\sin^{-1}\sqrt{P_2} = 2\sin^{-1}\sqrt{0.8} - 2\sin^{-1}\sqrt{0.69} = .25$
P is the proportion of correctly recalled behaviors for prosocials (P_1) and proselfs (P_2; Cohen, 1988, p .181).

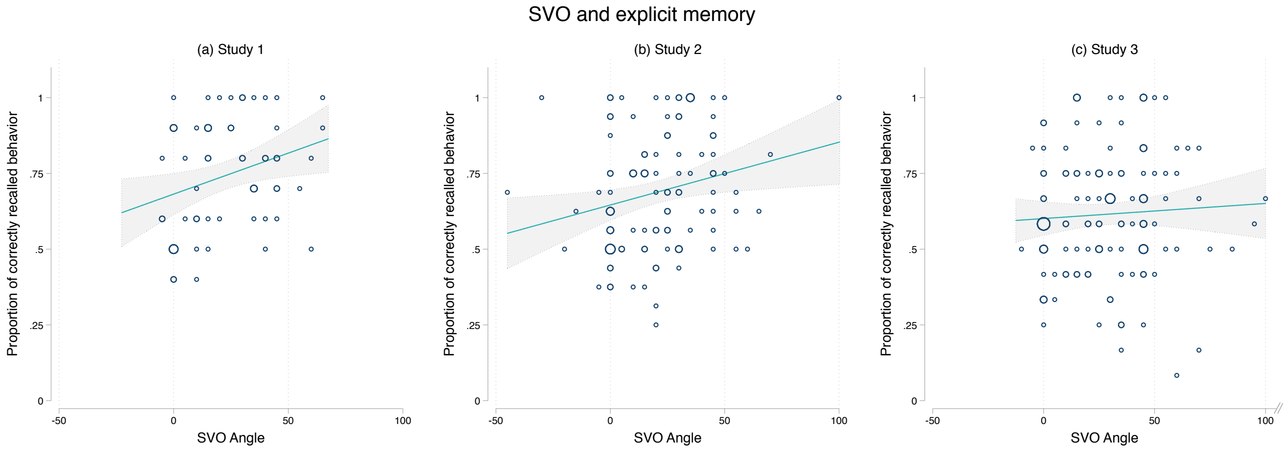

Figure 3. Proportion of correctly recalled behavior of the interaction partner, depending on SVO angle for all studies. SVO angle is displayed in 5° bins. Areas shaded in grey are 95% confidence intervals.

Predicting information search. In order to obtain an initial understanding of the underlying cognitive processes driving the effect of memory, we additionally analyzed response times in the encoding phase. To do so, we aggregated and log-transformed response times across items such that the sum of response times is computed for every item and subsequently log transformed. We were interested in both stages: (1) the feedback regarding the partner's behavior in the first stage of the encoding phase (partner's decision); and (2) the participant's own decision (own decision). In line with our pre-registered H2, SVO angle significantly predicts response time during encoding (β = .41, z = 3.25, p = .001). Specifically, more prosocial participants spend more time inspecting partners' decisions than more proself participants. The main effect of SVO on response times while receiving feedback about the partners' decision holds when controlling for the set of pre-specified control variables (Table 1). In contrast to H2, we do not find an effect of SVO angle on response time when participants were asked to make their own choice (β = .12, z = 1.49, p = .137). This result does not change when controlling for the pre-specified control variables (Table 1).

Table 1

Response time during encoding predicted by SVO angle

	Response time (log-transformed)			
	Partner's decision		Own decision	
SVO angle	0.39^{**}	(2.93)	0.10	(1.23)
Prosocial partner	0.03	(1.18)	0.01	(0.37)
Female participant	-0.16	(-1.41)	-0.10^{+}	(-1.72)
Female partner	0.09^{**}	(3.12)	0.03	(1.61)
Risk aversion	-0.01	(-0.08)	0.01	(0.23)
Attractiveness	-0.01	(-0.26)	-0.01	(-0.73)
Cost-benefit ratio	0.00	(0.05)	-0.02	(-0.92)
Constant	0.06	(0.52)	-0.06	(-0.87)
Observations	610			

Note. Standardized coefficients are reported; z statistics in parentheses, $^{+}$ p < .10, ** p < .01.

Mediation of the link between SVO and explicit memory. We used a mediation analysis to test our directed hypothesis that the effect of SVO angle on explicit memory is mediated by increased response times (H3) (see Figure 4).[6] As a first step, we included response time during encoding (partner's decision) in the logistic regression model predicting explicit memory performance. In doing so, we found that when including response time as an additional predictor, the influence of SVO angle on memory decreases (β = .20, z = 1.49, p =

[6] SVO angle does not significantly predict response time during participants' own decisions. Therefore, we only report the results using response time while receiving feedback about the partner's decision as a mediator here. For a mediation analysis including response time during participants' own decisions, see Table S5.

.137); and response time significantly predicts explicit memory performance (β = .25, z = 2.14, p = .032). For the mediation analysis, we cannot use the standard procedure proposed by Sobel (1982) as our model includes continuous and binary variables. Instead, we followed the analytical approach suggested by Karlson, Holm, and Breen (2010) using the KHB method, which estimates an indirect effect that is not distorted by differences in scales by rescaling the residuals' standard deviation.

We found a total effect of SVO on explicit memory in that SVO angle significantly predicts memory for an interaction partner's behavior. This effect is reduced for the direct effect when response time is added to the model. Overall, the total effect of SVO angle on explicit memory is 1.4 times larger than the direct effect. The indirect effect of SVO angle on explicit memory via response time indicates that the effect of SVO on memory is partially mediated by response time. Specifically, 28.59% of the total effect of SVO angle on explicit memory is due to response time.

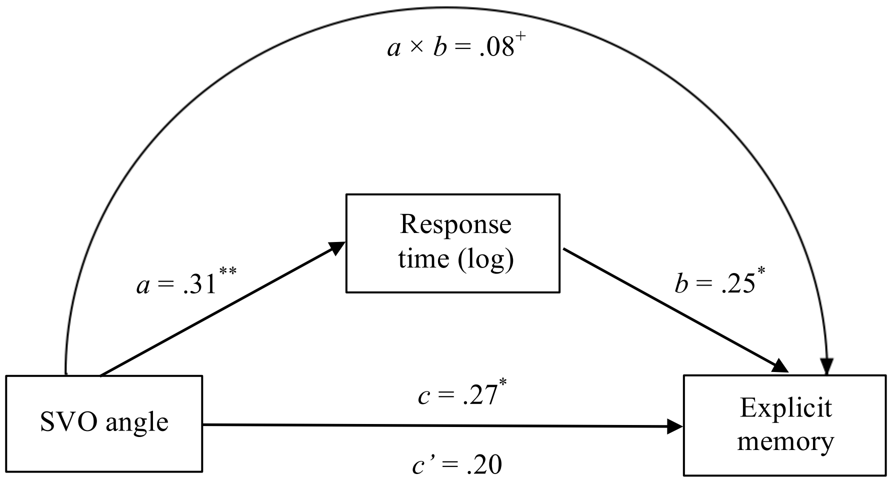

Figure 4. Illustration of mediation design with one mediating variable. The figure shows the effect of SVO angle on response time (*a*), the effect of response time on explicit memory (*b*), the total effect of SVO on memory (*c*), the direct effect of SVO on explicit memory mediated by response time (*c'*), and the indirect effect of SVO angle on explicit memory via response time ($a \times b$). Control variables are included and standardized coefficients are reported. For the indirect effect, standard errors are bootstrapped with 1000 repetitions. $^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$.

Discussion Study 1

Study 1 investigated whether an individual's social preferences are linked to memory performance in social interactions. Based on prior evidence that not only choice behavior but also underlying cognitive processes differ depending on individual social preferences, we postulated that more prosocial individuals would be more likely to recall their interaction partner's behavior (H1) than less prosocial individuals. Lending support to this hypothesis, our findings provide first evidence that an individual's social preference is indeed related to memory in social dilemmas. Thus, the notion that memory may be adaptively tuned to the specific challenges an individual faces receives initial support (Nairne et al., 2009). For prosocial individuals, remembering their partner's behavior is highly relevant in order to reciprocate and avoid exploitation. This is less important in the case of proself individuals. The results also show that the link between SVO and memory is partially mediated by response times. Prosocial individuals took longer when processing feedback about their partner's behavior and were subsequently better at recalling that behavior in a test of their explicit memory. This finding indicates that the link between SVO and memory is driven by differences in information search, which is in line with research suggesting that individuals exhibit different cognitive processes, depending on their SVO (Camac, 1992; Dehue et al., 1993; Fiedler et al., 2013). Regarding cheater detection (e.g., Buchner et al., 2009), we did not find evidence of a cheater-specific memory advantage. This finding is in line with current research suggesting that memory advantages for cheating behavior disappear when cheating is common and of low negative valence (Bell & Buchner, 2011; Bell, Koranyi, Buchner, & Rothermund, 2017; Volstorf et al., 2011).

More generally, the findings of Study 1 corroborate the idea that social preferences affect memory in social interactions and that this effect is partially driven by the extent of information search. Yet, it is still unclear which elements of the information search influence explicit memory. Going beyond response time predictions, Study 2 aimed to explore in greater detail the impact of visual attention as part of information search.

Study 2a & b

Building on the findings from Study 1, Study 2a extends the investigation by taking the role of visual attention into account. Utilizing eye-tracking to investigate the role of processing effort, we aimed at investigating individuals' information search in more detail. Eye movements were frequently recorded in previous studies to capture attention patterns in social, (e.g., Halevy & Chou, 2014), simultaneous (Lejarraga, Schulte-Mecklenbeck, & Smedema, 2017) and strategic interactions (N. Stewart et al., 2016). Eye-tracking makes it possible to unobtrusively assess how differences in attention allocation during encoding affect subsequent memory performance. Furthermore, Study 2a extends Study 1 by analyzing not only the link between SVO and explicit memory but also between SVO and implicit memory (described in detail below).

The aim of Study 2a was to replicate and extend the effect of SVO on explicit memory presented in Study 1. Specifically, we assume that individuals who are more prosocial are more likely to correctly recall the observed behavior of an interaction partner than less prosocial individuals (explicit memory, H1). Linked to this hypothesis, we assume that more prosocial individuals more often select a prosocial partner to interact with than less prosocial individuals (implicit memory, H2). Third, we hypothesize that more prosocial individuals exhibit a higher number of fixations when processing feedback about their partner's decision in the encoding phase (H3a) and direct a larger proportion of attention towards the interaction partner's payoffs than less prosocial individuals (H3b). Extending the mediating role of response time to attention, we assume that fixation number partially mediates the link between SVO and explicit memory (H4).

To test for long-term memory effects, we additionally conducted a follow-up study (Study 2b) after a period of three weeks. The aim of Study 2b was twofold: (1) to test how stable memory of interaction partners' behavior are across time and (2) whether individual differences in SVO extend to predict long-term memory performance.

Method

Participants. One hundred twenty-two participants from the Max Planck Decision Lab subject pool (students of the University of Bonn) were recruited via Orsee (Greiner, 2015). The experiment consisted of an online part and a part that was conducted at the Decision Lab. Together, both parts lasted a total of approximately one hour. Participants were fully incentivized, receiving a mean payoff of 12.40 Euros that varied according to their choices. The number of participants that were scheduled to take part in the study was set to 138 to account for dropouts. After excluding participants with incomplete data (n = 12), the final sample consisted of 110 participants (mean age = 23.14 years, 54.55% female). For all analyses including measures of fixation number, we excluded participants without eye-tracking data (n = 9), resulting in a sample of 101 participants (mean age = 23.15 years, 54.46% female). The mean SVO angle was 20.48° (SD = 21.69°). Fifty-one participants classified as prosocials; and 59 as proselfs.

Using data from the first study, we conducted an a priori simulation based power analysis aiming at a power of .8. This resulted in a target sample size of 100 complete data sets. For a more detailed description of the power analysis and sampling plan as well as the pre-registered hypotheses and analyses, see bit.do/Preregistration_Study2.

Materials.

Money allocation task. Participants encountered 8 different money allocation problems that constituted a subset of the 10 problems used in Study 1. Each problem consisted of option A and B, which differed with regard to the possible payoffs for the participant and the interaction partner.

Face stimuli. We used the same set of pictures as in Study 1, with an additional 6 faces to construct a complete set of 16 faces. The 16 faces were all rated as being moderately attractive (M = 2.15, SD = 0.12, range of the rating scale: (1) very unattractive – (4) very attractive).[7]

Memory ability. To control for individual differences in memory ability, participants completed the Verbal Paired Associates Memory (VPAM) subtest from the Wechsler Memory Scale-III, which measures verbal episodic memory. To complete the scale, participants first study specific word pairs and are then asked to indicate which words were presented together after a short delay. We used an adapted version that allows the test to be completed online (Germine et al., 2012; Wilmer et al., 2010). During the memorization phase, participants were presented with 25 word pairs, which were presented on screen one at a time for 6 s per word pair. In the test, participants were shown one of the words in each pair and asked to choose the second word from a list of four words.[8] The three distractor words were part of other word pairs. Memory ability was measured as the number of correctly recalled word pairs, which is referred to as the recall index and ranges from 0 (no word pair recalled) to 25 (all word pairs recalled).

The SVO ring measure, risk aversion measure, and attractiveness ratings of the faces were employed the same way as described in Study 1. A complete overview of the items, face stimuli, original instructions, and the *PsychoPy* program used in the experiment can be found here bit.do/Materials_Study2.

Procedure.

Online phase. At least 12 hours before taking part in the experiment, participants completed an online questionnaire. First, they completed the SVO ring measure (Liebrand & McClintock, 1988). Next, participants were informed that one of their choices in the subsequent phase would be presented to other participants in the laboratory. A battery of different choices including filler questions followed this instruction. As part of this battery,

---

[7] The additional faces were again selected based on previous attractiveness ratings (Hayn-Leichsenring et al., 2013)

[8] To construct an appropriate German version of the test, we used words that are frequently used in German and have a medium word length, measured in number of words (M = 5.94, SD = 0.84).

participants completed eight money allocation problems, one of which would later be presented to other participants in the laboratory, and the risk aversion measure (Holt & Laury, 2002). Each measure of the online questionnaire was fully incentivized in that one money allocation or lottery was randomly selected to be payoff-relevant.

Encoding phase. Upon arriving at the laboratory, participants were seated in front of a laptop (12.2" × 6.7" screen, color monitor with a native resolution of 1600 × 900). Viewed from a distance of 55 cm, the screen subtended a visual angle of 34° horizontally and 23° vertically. After reading the instructions, participants were calibrated to an EyeTribe eye-tracking device (9-point calibration, 30 Hz sampling rate, accuracy ~ 0.5°). In the first part of the experiment, participants observed their interaction partner’s choice in the money allocation problem, which were taken from participants’ responses in the online questionnaire. The procedure was the same as in Study 1 with a few adaptations. Rather than 10 interaction partners, participants encountered 16 interactions partners; and rather than 10 money allocation problems, participants were presented with 8 allocation problems. Each problem was presented twice but with a different partner. In addition, choices in the encoding phase were not incentivized but rather hypothetical. Finally, rather than 7 blocks, participants completed 10 blocks such that every interaction partner was presented 10 times. We adapted the number of interaction partners to increase the number of trials and thereby reduce noise. We assumed that participants’ attention span would be higher in the laboratory than in an online study, remembering more partners with a higher number of repetitions is a more feasible task when in a controlled environment. After completing all blocks, a short distractor task was conducted that asked participants to count specific symbols and then enter the correct number.

Implicit memory phase. In the implicit memory phase, participants were presented with two potential interaction partners and the respective money allocation problem. Both interaction partners were presented with the same money allocation problem that they had been presented with during the encoding phase. They were instructed to select the partner they preferred to interact with as a means to determine their payoff. Participants were informed that the position of the presented partners was not related to the option they had previously chosen. Choices were fully incentivized in that one interaction was randomly selected and paid out at the end of the experiment.

Unfortunately, a substantial proportion of participants misunderstood the implicit memory task. The interaction partners were presented on the left or right side of the screen, with the money allocation payoff matrix presented in the middle. Instead of choosing the partner who had made a prosocial decision during the encoding phase to maximize their payoff, participants' choices were driven by the position of the prosocial option in the payoff matrix, with a majority choosing the partner who was presented next to the prosocial option. Considering these findings, we refrained from conducting the planned analysis for the implicit memory task.[9]

Explicit memory phase. In the subsequent explicit memory phase, participants were asked to recall their interaction partners' behavior during the encoding phase. Again, the procedure in this phase was identical to Study 1.

Data Preparation.

Areas of interest. Overall, 5 non-overlapping areas of interest (AOIs) were defined: 2 AOIs containing the participant's own payoffs (310 × 250 pixels with a margin of 140.5 × 117.5 pixels); 2 AOIs containing the interaction partner's payoffs (310 × 250 pixels with a margin of 140.5 × 117.5 pixels); and 1 AOI containing the face used as the profile picture (375 × 450 pixels with a margin of 68.5 × 75 pixels). Other AOIs included text labels for the payoff matrix, which were not included in the analysis. We constructed the stimuli such that the distance between objects and the AOI margin was maximized, following suggestions by

[9] See the supplementary material for a more detailed explanation and a screenshot of the decision situation (Figure S2).

Orquin et al. (2016).[10] Fixations were defined as relative stable gaze (raw data points are located with a radius of 30 pixel) lasting at least 50 ms (Salvucci & Goldberg, 2000).

Data analysis. To test whether social preferences have an impact on memory for interaction partner's behavior, we again used a repeated measures logistic regression predicting memory accuracy by SVO angle and calculated robust standard errors. Using a mediation analysis, we then tested whether the extent of information processing, measured by the number of fixations, mediates the effect of SVO angle on memory accuracy. For fixation number, we used the total number of fixations for each item. To test for a normal distribution of fixation number, we used the Shapiro-Wilk test. The results indicated that the distribution is skewed ($W = 0.95$, $z = 9.96$, $p < .001$); consequently, we log-transformed fixation number. When including an interaction effect in a model, we centered all involved predictor variables. When predicting explicit memory performance, we controlled for a set of pre-specified variables, namely participant's gender, interaction partner's gender, cost-benefit ratio of the item, attractiveness of the faces, memory ability, and the observed behavior (prosocial vs. individualistic choice). The position of the partner's payoffs in the on-screen matrix (top row vs. bottom row) was found to have an influence on an individual's attention allocation. Thus, when predicting attention to other's payoffs, we additionally controlled for the position at which other's payoffs were presented. For the analysis script and data, see bit.do/Analysis_Study2. For a pre-processing script as well as the raw data, see bit.do/Data_Study2.

Results

Predicting explicit memory performance with SVO. Overall, participants correctly recalled the behavior of 68.81% of their interaction partners. The correct explicit memory rate was 75.12% for prosocial and 63.35% for proself participants (Cohen's $h = .26$). To test our

[10] For a visual presentation of the AOIs position on the screen, see Figure S3.

first directed hypothesis, namely that more prosocial individuals are more likely to correctly recall their interaction partner's behavior than less prosocial individuals (H1), we predicted the correct recall of an interaction partner's behavior using SVO angle. The results show that individuals with a higher SVO angle (more prosocial) recall their interaction partners' behavior in the encoding phase better (β = .26, z = 2.11, p = .035, see Figure 3b).[11] More specifically, using marginal predictions we find that the probability for recalling the partner's behavior correctly was 9.70% higher for ideal prosocials than for ideal proselfs. Testing for the influence of interaction partner's type on explicit memory, the results again reveal no significant effect (β = .03, z = 0.33, p = .742).

Predicting information search with SVO. Taking a closer look at the underlying drivers of the effect of SVO on explicit memory, we additionally analyzed attention processes in the encoding phase. Specifically, we were interested in whether the number of fixations individuals exhibit while observing the interaction partner's decision, as well as the proportion of attention directed towards the interaction partner's payoffs, depends on a person's SVO. In line with our directed Hypothesis H3a yet non-significant, the results suggest that prosocial individuals may exhibit a higher number of fixations while receiving feedback about the partner's decision than individuals who are less prosocial (see Table 2a).[12] However, SVO significantly predicts the proportion of attention that is directed towards the partner's payoffs while receiving feedback about the partner's decision, which is in line with the pre-registered Hypothesis H3b (Table 2b).

[11] This effect also holds for the simple effect of SVO on explicit memory without controls (see Table S6).
[12] This effect is significant in the simple regression without controls (β = .14, z = 1.65, p = .099; see Table S7).

Table 2

Information search predicted by SVO angle while receiving feedback about the partner's decision

	(a) Fixation number (log)		(b) Proportion of attention to partner's payoffs	
SVO angle	0.12	(1.23)	0.16^{**}	(2.95)
Control factors	YES		YES	
Constant	-0.00	(0.00)	0.00	(0.00)
Observations		1616		

Note. Standardized coefficients, *z* statistics in parentheses. Fixation number is log-transformed. Control factors include the partner's attractiveness, the cost-benefit ratios, risk aversion, memory ability, and the position of the partner's payoff. ** $p < .01$.

Predicting memory performance with information search. In a next step, we examined whether information search (measured through fixation number) while receiving feedback about the partner's decision during the encoding phase influenced memory. Predicting explicit memory performance with fixation number indicated that, as the number of fixations increased, correctly recalling an interaction partner's behavior became significantly more likely ($\beta = .40$, $z = 5.02$, $p < .001$; see also Figure 5a).

In exploratory analyses, we also used the proportion of attention directed towards the partner's payoffs and the proportion of attention directed towards the interaction partner's face to predict explicit memory. Our findings show that individuals were more likely to correctly recall their partner's behavior if they directed more attention to their partner's payoffs while receiving feedback about the partner's decision during the encoding phase ($\beta = .24$, $z = 2.78$, $p = .005$, see also Figure 5b). Likewise, an increase in the proportion of attention directed towards the partner's face (log-transformed) was associated with a higher likelihood of correctly recalling the partner's behavior ($\beta = .17$, $z = 2.04$, $p = .041$, see also Figure 5c).

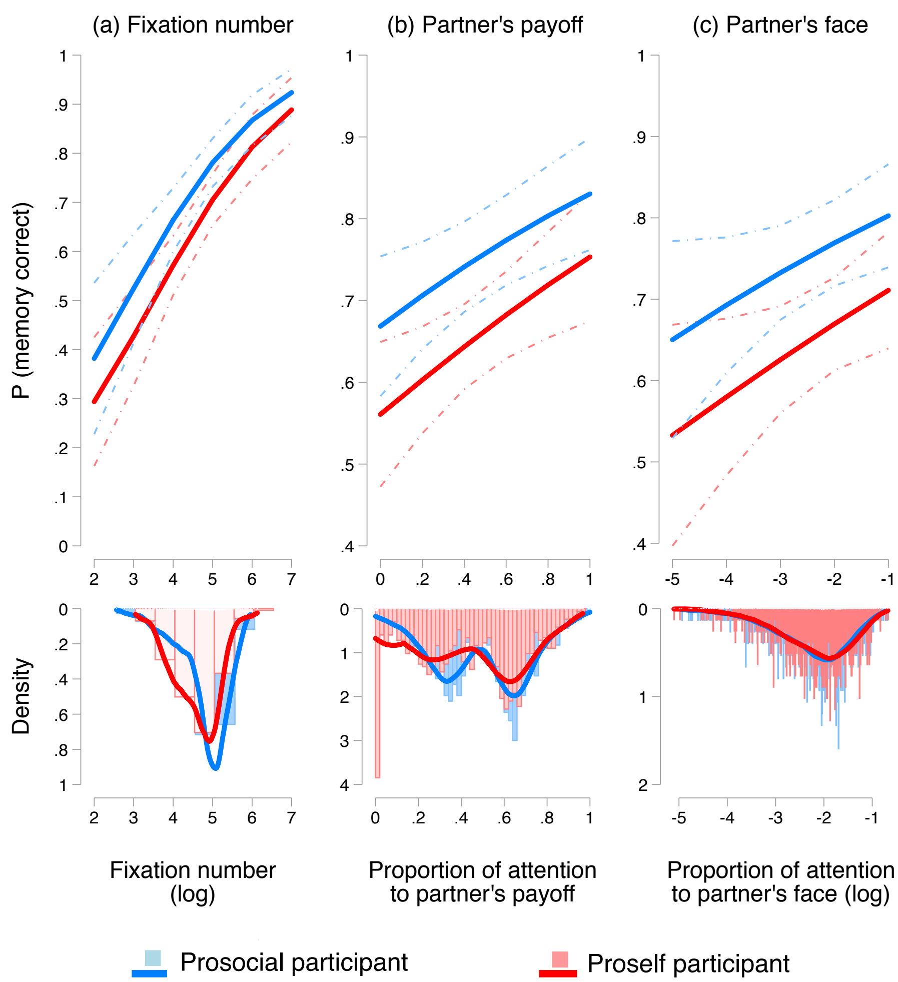

Figure 5. The probability of recalling the observed player's behavior correctly depending on (a) mean fixation number, (b) proportion of attention towards the partner's payoffs, and (c) proportion of attention to the partner's face. Dotted lines indicate 95% confidence intervals. The histograms in the bottom column indicate the relative frequency of observations on the corresponding x-axis variable separately for prosocial and proself participants. For further details on the statistical analysis, see Table S8.

Mediation of the link between SVO and explicit memory with information search. To investigate whether attention processes drive the effect of SVO on explicit memory accuracy, we again used a mediation approach (H4). Following our pre-registered hypothesis, we used fixation number as a mediating variable of the link between SVO and explicit memory, rather than attention directed to the other's payoff or face. As a first step, we included fixation number during encoding in the logistic regression model predicting explicit memory performance. We found that when including fixation number as an additional predictor, the influence of SVO angle on explicit memory decreases (β = .15, z = 1.47, p = .142) and fixation number significantly predicts memory performance (β = .40, z = 5.03, p < .001). For the mediation analysis, we followed the analytical approach described in Study 1 – that is, we rescaled and bootstrapped the indirect effect. The results indicate that, in terms of the total effect when fixation number is not included in the model, SVO angle significantly predicts explicit memory for the interaction partner's behavior. This effect decreases for the direct effect when fixation number is added to the model. Overall, the total effect of SVO angle on explicit memory is 1.31 times larger than the direct effect. In support of H4, the indirect effect of SVO angle on explicit memory via response time indicates that fixation number partially mediates this effect. Specifically, 23.55% of the total effect of SVO angle on explicit memory is driven by fixation number (see Figure 6).[13]

[13] For a replication of the analysis using response time as a mediator of the effect of SVO on memory, see Table S9.

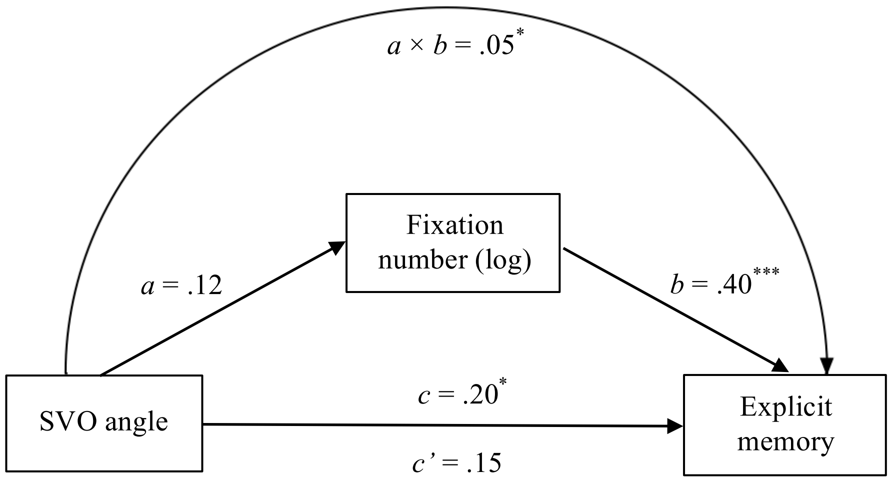

Figure 6. Illustration of mediation design with one mediating variable. The figure shows the effect of SVO angle on fixation number (*a*), the effect of fixation number on explicit memory (*b*), the total effect of SVO on memory (*c*), the direct effect of SVO on explicit memory mediated by fixation number (*c'*), and the indirect effect of SVO angle on explicit memory via fixation number ($a \times b$). Control variables are included; and standardized coefficients are reported. For the indirect effect, standard errors are bootstrapped with 1000 repetitions. $^{*}p < .05$, $^{***}p < .001$.

Study 2b (long-term effects)

To explore the link between SVO and long-term implicit and explicit memory, we contacted all 101 participants again after three weeks. Due to the aforementioned misunderstanding of the original implicit memory task, we adapted the presentation screen so that, for the implicit decision only, the interaction partners' faces were on the screen, omitting the payoff matrix (see Figure S4, implicit memory phase).

Method

Participants. All participants had the chance to win a fixed payoff of 46 Euros and an additional, variable payoff. The variable payoff was determined by realizing one of the choices in the implicit memory phase and an additional 10 cents for each correctly remembered behavior. Out of the 101 participants, 90 took part in the follow-up study (mean age = 23.92 years, 54.44% female). To test for selection effects due to attrition, we compared the distribution of participants' SVO angles in both waves. The distribution of SVO angles in Study 2b is not significantly different from the distribution in the overall sample, $t(198) = .886$, $p = .930$. See bit.do/Longterm_Study2 for materials, raw data, and the complete analysis of the follow-up study.

Procedure. In the follow-up study, participants again completed six trials in which they were asked to choose one of two presented partners that they had interacted with three weeks earlier to allocate money for them (implicit memory). Afterwards, participants were again asked to remember the behavior of each partner (explicit memory) as well as the attractiveness ratings of the faces for an unrelated study.

Results

Predicting memory performance.

Implicit Memory. Overall, in 63.75% of the trials, a prosocial partner was selected to allocate the money. Including the pre-specified control variables, the results show no link between SVO and implicit long-term memory (β = .005, z = 0.04, p = .970).

Explicit Memory. Testing also explicit memory performance, the results show that participants correctly recalled the interaction partners' behavior in 60.97% of the trials. Therefore, the rate of correctly recalling interaction partner's behavior decreased by 13.52% across the time span of three weeks. The correct explicit memory rate was 63.81% for prosocial and 58.38% for proself participants. The results indicate that the link between SVO and explicit memory does not prevail over time (β = .10, z = 1.21, p = .227). Testing for the cheater-memory hypothesis, the results again show no evidence of an influence of the partner's type on explicit long-term memory (β = .14, z = 1.43, p = .152).

Discussion Study 2

The findings of Study 2 provide additional evidence for a link between an individual's SVO and their short-term memory for behavior in social interactions. Successfully replicating the results of Study 1, more prosocial individuals were more likely to correctly recall their interaction partner's behavior. Analyzing in more detail the role and elements of information search in this relationship, we measured the extent of information search in a more detailed manner using eye-tracking. In contrast to Study 1, the collected measures included number of fixations and attention distribution. The results show that more prosocial individuals exhibit higher numbers of fixations and direct more attention to the partner's payoffs while receiving feedback about the partner's decision. Paying more attention to an interaction partner's face or payoff is related to better memory. Furthermore, as predicted the number of fixations when encoding information about the partner's decision partially mediates the effect of SVO on memory performance. These results are in line with previous findings suggesting that memory abilities are related to attention processes during encoding, where attended information is more likely to be recalled (Chun & Turk-Browne, 2007). More specifically, these findings corroborate the important role fixations have in predicting subsequent memory that was suggested by previous research (Bloom & Mudd, 1991; Kafkas & Montaldi, 2011). To test for boundary conditions of this effect, Study 2b additionally tested long-term effects of SVO on memory. The results no longer show a significant relationship between SVO and explicit long-term memory as well as no link to implicit memory.

The lack of an effect on long-term memory is in line with the results of Volstorf et al. (2011), who also found a decrease in memory accuracy for social interaction partners after a retention interval of one week. The fact that memory performance declines with longer retention intervals is one of the earliest laws discovered in psychology (Brown, 1958; Rubin & Wenzel, 1996). Given that the average memory rate was only approximately 69% after a brief delay of several minutes, we possibly faced floor effects for an interval of three weeks. After this fairly long retention interval, the average memory rate decreased to approximately 61%, making it difficult to detect differences driven by social preferences.

Study 3

The evidence of Studies 1 and 2a connects explicit short-term memory performance to individual SVO. We conducted Study 3 in order to replicate the findings concerning the link between explicit memory and SVO and, in particular, test whether this effect extends to implicit short-term memory. As empathy was found to be related to prosociality as well as the ability to recognize facial expressions (Declerck & Bogaert, 2008), the study material from the first two studies was extended to include this pre-test measure, which was then used as a control variable. Following a procedure similar to Study 1 and 2, participants chose one of two players to determine their own payoff in a money allocation task after observing their previous choices. Assuming that prosocial individuals are more likely to correctly recall their interaction partner's previous behavior, we hypothesized that more prosocial individuals would be more likely to select the prosocial rather than individualistic player.[14]

Method

Participants. One hundred thirty-seven participants from the Max Planck Decision Lab subject pool (students of the University of Bonn) were recruited via Orsee (Greiner, 2015). The experiment was conducted online via the platform *Unipark* and lasted approximately 45 minutes. Participants were fully incentivized and received a mean payoff of 9.50 Euros that varied according to their choices. Using data from the first study, an a priori, simulation based power analysis aiming at .85 revealed a target sample size of 130 complete data sets. The pre-registered number of participants who were scheduled to take part in the study was set to 143 to account for dropouts. Six participants did not take part in the study. In addition, we excluded 3 participants who did not complete the experiment. This resulted in a final sample of 134 participants (mean age = 21.5 years, 50% female). The mean SVO angle was 28.58° (*SD* = 24.26°), with 79 participants classified as prosocials and 55 as proselfs.

[14] To ensure that there would be no misunderstandings in the adapted task, we pre-tested the stimulus material in Study 2b. The results revealed that there were no difficulties understanding the adapted task.

Materials.

Money allocation task. Participants encountered 6 different money allocation problems that constitute a subset of the 10 tasks used in Study 1. Each problem consisted of option A and B, which differed in terms of the possible payoffs for the participant and the interaction partner (see Figure 2).

Face stimuli. The stimulus set consisted of 12 faces to include an equal number of male and female faces for the implicit memory task. In order to test for any stimulus dependencies, we compiled two distinct face sets of 12 faces each, resulting in an overall number of 24 faces. All stimuli were rated[15] as being moderately attractive (16 were also used in Study 1 and 2). Faces were randomly distributed across two sets (Set 1: $M = 2.21$, $SD = 0.17$, Set 2: $M = 2.25$, $SD = 0.17$, range of the rating scale: (1) very unattractive – (4) very attractive). We randomized between-subjects with which behavior (prosocial or individualistic) a face was presented.

Interpersonal Reactivity Index. The Interpersonal Reactivity Index (Davis, 1980) uses a multidimensional approach to capture individual differences in empathy. It defines empathy as the "reactions of one individual to the observed experiences of another". It consists of 28 items on a 5-point Likert scale ranging from "Does not describe me well" to "Describes me very well". The measure has 4 subscales, namely perspective taking (i.e., "I try to look at everybody's side of a disagreement before I make a decision."), fantasy (i.e., "I really get involved with the feelings of the characters in a novel."), empathic concern (i.e., "I often care about people less fortunate than me."), and personal distress (i.e., "In emergency situations, I feel apprehensive and ill-at-ease.").

The SVO ring measure, risk aversion measure, and attractiveness ratings of the faces were employed as described in Study 1. A complete overview of the items, original

[15] The additional faces were again selected based on previous attractiveness ratings (Hayn-Leichsenring et al., 2013).

instructions, and the *Unipark* program of the experiment can be found here: bit.do/Material_Study3.

Procedure.

Encoding phase. The encoding phase was identical to Study 1 but participants interacted with 12 rather than 10 partners. We increased the number of interaction partners from 10 to 12 to ensure that we presented the same number of female and male face pairs.

Implicit memory phase. In the implicit memory phase, participants were presented with two interaction partners. Similar to Study 2a, participants had observed the behavior of two interaction partners for each money allocation problem during the encoding phase. In contrast to Study 2a, we presented the two interaction partners without the money allocation problem on the screen to avoid misunderstandings. Pictures of the interaction partners were presented on the far left and far right side of the screen (See Figure S4). Participants then selected the partner they wished to allocate the money between themselves and their partner. To minimize differences in attractiveness within the 6 pairs of potential partners, we matched the two faces again according to gender and previous attractiveness ratings (Hayn-Leichsenring et al., 2013). Each of the pairs consisted of a prosocial and an individualistic partner (location of each partner was randomized within participant). Choices were fully incentivized, in that one interaction was selected at random and paid out at the end of the experiment.

Explicit memory phase. In the subsequent explicit memory phase, participants were asked to recall their interaction partners' behavior during the encoding phase. Again, the procedure in this phase was the same as in Study 1. See Figure S4 for the adapted procedure.

Data analysis. Following the same approach as in Study 1 and 2, we used a repeated measurement logistic regression predicting memory accuracy by SVO angle and calculated robust standard errors. Analyzing the influence of SVO angle on response time, we used a repeated measures linear regression. The Shapiro-Wilk test again indicated a skewed distribution of response times (*W* = 0.63, *z* = 12.15, *p* < .001). Consequently, we log-transformed response time. Using a mediation analysis, we tested whether the effect of SVO angle on memory accuracy is mediated by response times. When predicting implicit memory performance, pre-specified control variables included the participant's gender, the interaction partner's gender, the cost-benefit ratio of the item, the attractiveness of the faces, and empathy. For analyses on explicit memory performance, observed behavior (prosocial vs. individualistic choice) was added as an additional control variable. Raw data can be found here bit.do/Data_Study3, whereas a detailed description of all analyses can be found here bit.do/Analysis_Study3.

Results

Predicting memory performance.

Implicit memory. Overall, participants chose a prosocial interaction partner to allocate the money in 67.41% of the trials. A prosocial interaction partner was selected in 67.93% of the trials by prosocial participants and 66.67% of the trials by proself participants. To test our pre-registered hypothesis that more prosocial individuals are more likely to select a prosocial partner to interact with than less prosocial individuals (H1), we predicted the choice of a prosocial interaction partner using SVO angle. The findings indicate that individuals with a higher SVO angle (more prosocial) do not significantly differ from less prosocial individuals in terms of their choice of interaction partner (β = -.02, *z* = -0.17, *p* = .861).

Explicit memory. In terms of explicit memory performance, the results reveal that participants correctly recalled their interaction partner's behavior in 61.50% of the trials. The correct explicit memory rate was 62.24% for prosocial and 60.45%for proself participants. Testing the link between SVO and explicit memory established in Study 1 and 2a (H2) showed that, in Study 3, SVO did not significantly predict explicit memory (β = .04, *z* = 0.60, *p* = .552, see Figure 3c). Testing the cheater-memory hypothesis, the analyses again reveal no significant effect (β = .10, *z* = 1.29, *p* = .198).

Predicting information search. In contrast to H3, which assumes that more prosocial individuals are more likely to exhibit longer information search, the results showed no statistically significant link between SVO and response times when receiving feedback about the partner's choice (β = .11, *z* = 1.59, *p* = .113).

Discussion Study 3

In Study 3, we did not replicate the effect of SVO on explicit memory established in Study 1 and 2a. There are two potential reasons for this. First, the overall explicit memory rate decreased from 74.26% (Study 1) to 61.50%, possibly due to changes in the difficulty of the memory task (84 trials during encoding rather than 70 trials). The baseline memory rate is potentially too low to detect differences in explicit memory due to SVO. Second, based on the power analysis, the chance of not finding an effect with the given sample size is 15%. Highlighting the problem of Type II errors, Schimmack (2012) argued that multiple-study articles do not provide more credible evidence by replicating results repeatedly given the modest power of individual studies. To maintain credibility, he suggests that, rather than increase the number of studies, the total power should be maximized. Thus, in order to obtain a more comprehensive understanding of the link between SVO and memory and to increase total power, we used a meta-study approach to examine the effect of SVO on explicit memory across all three studies.

Meta-study

In order to test for the overall effect of SVO on memory, we pooled the data across Study 1 to 3. The resulting increase in sample size and heterogeneity of the stimulus material of this joint analysis thus provides a robust estimation of systematic differences in explicit memory due to SVO.

Predicting memory performance. We conducted a mixed-effects, repeated measures logistic regression including the previously pre-registered control factors, a dummy for study 1-3, and a dummy for study type (online vs. lab). The results confirm a positive relation between prosociality and memory performance ($\beta = .17$, $z = 2.80$, $p = .005$, see Figure 7). More specifically, marginal predictions show that the probability of correctly recalling the partner's behavior was 6.45% higher for ideal prosocials than for ideal proselfs. In addition, when testing the cheater-detection hypothesis overall, the results show no link between the interaction partner's past behavior and explicit memory of their behavior ($\beta = .04$, $z = 0.71$, $p = .479$).

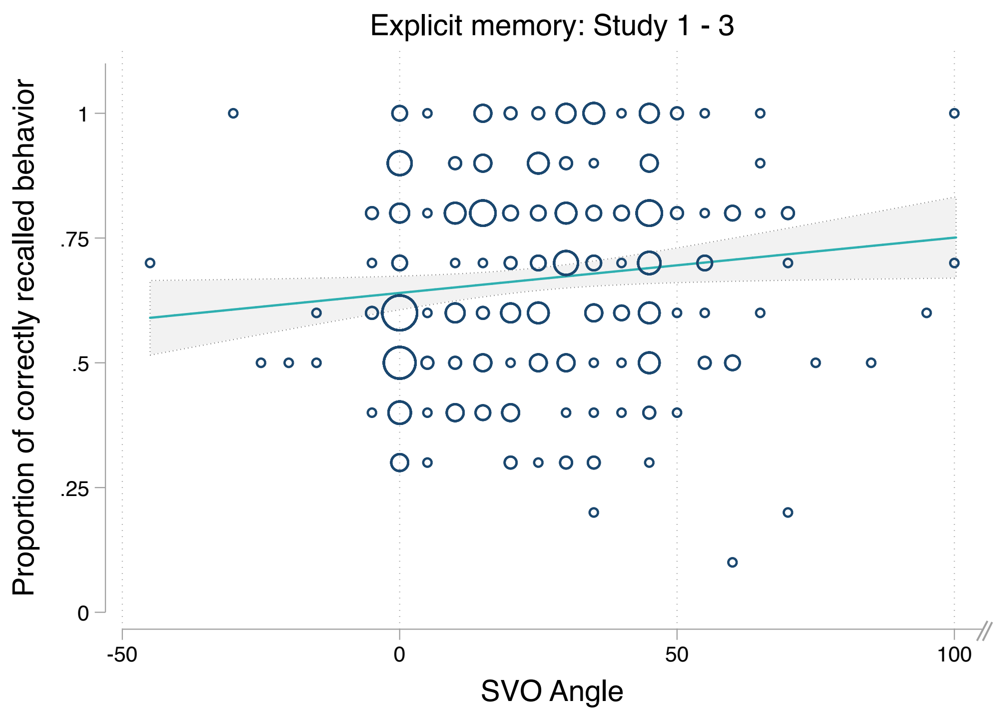

Figure 7. Proportion of correctly recalled behavior of interaction partner, depending on SVO angle. SVO angle is displayed in 5° bins, whereas proportion of correct recall is displayed in 0.1 bins. Areas shaded in grey are 95% confidence intervals. $N = 305$.

To test the role of the information search channel, we analyzed response times while receiving information about the others choice across all studies. The results of a mixed-effects regression including control factors as well as study and study type dummies show that SVO angle significantly predicts response time during encoding ($\beta = .08$, $z = 3.36$, $p < .001$). Specifically, more prosocial participants spend more time inspecting the partner's decision than proself participants. To test whether response time mediates the effect of SVO on explicit memory, a mediation analysis – following the same method described in Study 1 and 2a (and additionally controlling for study and study type) – was conducted. The results of the mediation analysis revealed that the total effect of SVO angle on explicit memory is 1.21 times larger than the direct effect. The indirect effect of SVO angle on explicit memory via response time indicates that the effect of SVO on memory is partially mediated by response time (see Figure 8). Specifically, 17.64% of the total effect of SVO angle on explicit memory is due to response time.

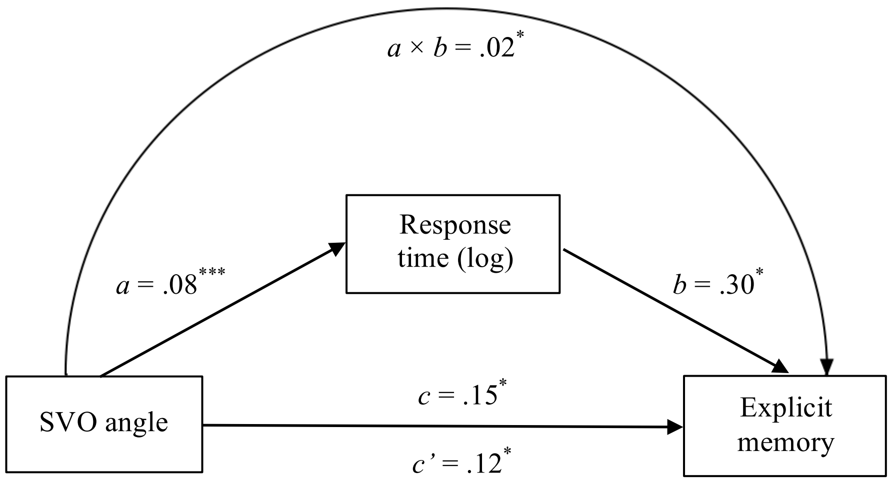

Figure 8. Illustration of mediation design with one mediating variable. The figure shows the effect of SVO angle on response time (*a*), the effect of response time on explicit memory (*b*), the total effect of SVO on memory (*c*), the direct effect of SVO on explicit memory mediated by response time (*c'*), and the indirect effect of SVO angle on explicit memory via response time ($a \times b$). Control variables are included; and standardized coefficients are reported; * $p < .05$, *** $p < .001$.

General Discussion

In three preregistered studies (*N* = 305, two online studies and one eye-tracking study), we investigate the link between social preferences (measured through SVO) and recall of an interaction partner's cooperation behavior. The results show that prosocial individuals are more likely to recall interaction partner's past behavior than proself individuals. Going beyond this simple observation of choice behavior, process analyses indicate that the link between SVO and explicit memory is partly driven by the extent of information search during the first interactions. More prosocial individuals take longer to encode information regarding their partner's behavior and exhibit more thorough information search (i.e., higher number of fixations). Testing for boundary conditions of the effect of SVO on memory, we additionally investigated the link between SVO and long-term memory for social interaction partners (Study 2b). The results indicate that the influence of SVO on memory did not persist over a retention interval of three weeks.

These results are noteworthy in several respects. First, this research is, to our knowledge, the first to adopt an individual differences approach to examine the role of memory in social interactions. Second, the findings shed light on one crucial channel through which social preferences affect memory performance. By providing converging evidence that the extent of information search contributes to the memory advantage of prosocials, this work highlights the importance of cognitive processes in the emergence of cooperation. Third, the studies exhibit high external validity, as participants passed through fully incentivized interactions and formed their own impressions via repeated contact.

Drivers of the link between social preferences and memory

The present results successfully replicate previous research (Fiedler et al., 2013) by showing that more prosocial individuals are more likely to take longer and exhibit a higher number of fixations when searching for information in social dilemmas. These findings go even further by showing support for a mediating role of information search. Notably, this provides first evidence that differences in cognitive processes not only explain immediate choice behavior but also are linked to memory performance in people facing a social dilemma.

Investigating the differences in information search in more detail, Study 2 revealed that more prosocial individuals not only took longer for each interaction but also directed a higher proportion of attention to the interaction partner's payoffs. With more extensive encoding of the decision problem, prosocial individuals have a more accurate memory representation of previous interactions. Additionally, when participants direct more attention to their partner's face, subsequent memory of the partner's behavior is improved. Similarly, previous research found that exposure time to a face successfully predicts identification accuracy (Bornstein et al., 2012; Laughery et al., 1971). Beyond facial identification, the present findings suggest that more elaborate encoding of the partner's face might serve as an additional cue for the behavior associated with that face.

By utilizing process data to study these driving factors on a more fine-grained level, we contribute to a more detailed understanding of memory processes in social interactions. An interesting explanation for the observed link between social preferences and memory can be found in work on social networks. Whereas previous evidence suggests that network size is determined by individual differences in prosocial behavior (Layous, Nelson, Oberle, Schonert-Reichl, & Lyubomirsky, 2012), Wink and Stevens (2017) show that memory accuracy for an interaction partner's behavior increases with the decision makers' social network size. Assuming that prosociality is associated with larger social networks, our results suggest that the link between prosociality and memory capacity could be driven by differences in the environments that prosocials create for themselves.

Memory in the emergence of cooperation

The presented evidence is strongly in line with propositions of the social exchange theory highlighting memory as one of the essential cognitive capacities required for social interactions (Cosmides & Tooby, 1989). Following this account, memory is a necessary prerequisite in order to keep track of an individual's behavior and ultimately resembles a key feature in the emergence of reciprocal strategies. This is particularly important for individuals who have a preference for cooperation. By being able to remember their interaction partner's behavior, they are able to maintain cooperation across time and avoid being exploited by defectors (Feyer, Leopold-Wildburger, & Pickl, 2007). Explaining prosocials' memory advantage from an evolutionary perspective, it could be argued that the additional effort invested in information search and processing is a natural consequence of their underlying preference for cooperation.

Going beyond general requirements for social interactions, the social exchange theory claims that individuals have a specific module for detecting cheaters in adaptation to evolutionary challenges (Cosmides & Tooby, 1989). There is first evidence in favor of a cheater-specific memory effect was presented (e.g., Mealey et al., 1996); however, other studies have failed to replicate that effect (e.g., Barclay & Lalumière, 2006). Our results replicate those null findings and show no evidence for preferential memory of individualistic behavior within simple decomposed dictator games. One alternative explanation that was put forward is a general strategy to remember rare interaction partners (Volstorf et al., 2011). However, in the current studies, all partners were encountered equally often. Consequently, the results provide no answer concerning a rarity advantage.

Future Directions and Implications

The current studies offer a number of interesting directions for future research. First, the results of Study 2b suggest that the effect of social preferences on memory performance is sensitive to the time between initial interaction and recall. These changes in memory performance call for a systematic investigation of the development of the postulated memory advantages of prosocial participants.

Second, in the present studies, participants were not explicitly instructed to remember their interaction partners' behavior. An interesting avenue for future research would be to investigate whether memory performance could be influenced by such an instruction. For example, when lending money to someone, the incentive to remember a person's behavior is high and could crowd out any differences in memory driven by SVO.

Considering the number of social interactions we experience in everyday life, the present findings have important practical implications. Presumably, prosocial individuals are better equipped to engage in cooperative social interactions, as they form more accurate expectations of their partner's future behavior. For example, when working on a joint project with a coworker, paying attention to the consequences of working together not only for oneself but also for the coworker can facilitate recalling that coworker's behavior later. When deciding whether to engage in a joint project again in the future, this information can be recalled and expectations regarding the coworker's future behavior adjusted accordingly. Importantly, remembering previous behavior can sustain cooperative actions between prosocial coworkers. Engaging in bilateral cooperation across long periods of time is beneficial not only to coworkers but also to the company for which they work. Given the crucial economic and societal benefits of engaging in cooperative social interactions, it is important to note that a lack of memory is a possible reason for systematic deviations from cooperation. From an evolutionary perspective, memory for interaction partners is crucial to avoid exploitation, which is especially costly for prosocials. In conclusion, the overall results of the three studies indicate that individual's social preferences predict their explicit short-term memory performance in social interactions. The presented evidence supports the notion that memory is adaptively tuned to the specific challenges that individuals face, depending on their social preferences.

Chapter II

Social Value Orientation predicts information search in strategic environments: An eye-tracking analysis

Minou Ghaffari [a, b] & Susann Fiedler [a]

[a] Max Planck Institute for Research on Collective Goods

[b] University of Zurich

This article was submitted for publication to the *European Journal of Social Psychology*.

Abstract

Understanding cooperation in strategic interactions is essential for the well being of individuals and societies. Using eye-tracking, the current study investigates the influence of other-regarding preferences on cognitive processes in a strategic environment ($N = 73$). Specifically, this work examines the impact of Social Value Orientation (SVO) on information search in a simple symmetric prisoner's dilemma. Reporting gaze behavior and participants' subsequent choices, our findings reveal that prosocial individuals are more likely to attend to the cooperative strategy and their partner's payoff than individualists. Interestingly, these differences extend to the magnitude of the gaze cascade effect, reflecting higher levels of motivated information search for prosocials. Cooperative choices were associated with shorter information search and more attention to the cooperative strategy than defective choices. Overall, the findings indicate that during strategic considerations in social dilemmas, eye movements reflect differences in other-regarding preferences.

Keywords: information search, prisoner's dilemma, eye-tracking, social value orientation, process tracing

Introduction

In many societal problems, individuals exhibit a conflict between keeping resources (e.g., money, time or attention) to themselves and sharing them with another individual or group. Such a conflict is the defining feature of a social dilemma. For example, company employees who compete with each other are often subject to such a dilemma. They can either support their colleague and potentially receive support in return or focus on getting ahead without losing any time. The company benefits most if employees support each other in their tasks, but any single employee would be best off by receiving support from their colleague without returning the favor. How individuals behave in such situations is of central interest to social scientists, because creating institutional frameworks that foster the evolution of cooperation, are crucial for well-functioning organizations as well as society. One widely-used paradigm to study behavior in strategic social situations is the prisoner's dilemma with imperfect information (e.g., Rapoport & Chammah, 1965). This particular game is a theoretical representation of strategic decision making, where two players simultaneously have to choose either to cooperate or defect. Both players are completely informed about the consequences of each outcome as well as the incentives of the other player. Fueled by narrow self-interest the dominant decision within this game structure is to defect, even though mutual cooperation would be better for both players.

Deviating from predictions of standard economic theory, the empirical literature provides evidence that there is substantial behavioral heterogeneity within this economic paradigm (e.g., Axelrod & Hamilton, 1981; Dawes & Thaler, 1988). One of the most prominent approaches to explain these inter-individual differences in strategic cooperation are social preferences. Social preferences are exhibited when people are not solely motivated by their material self-interest, but also care positively or negatively for the outcomes of others (Fehr & Schmidt, 1999). Evidence for a link between choice behavior and social preferences has been repeatedly shown (for overviews see Balliet et al., 2009; Bogaert et al., 2008), and studies investigating beliefs and expectations within strategic interactions provide first indications for a heterogeneity also within the mental representation of these decision situations (Smeesters, Warlop, Van Avermaet, Corneille, & Yzerbyt, 2003; Van Lange, 1992). Yet, an understanding of the underlying motivational mechanisms of strategic social decision making is largely lacking.

In this study, we aim to shed light on the cognitive channels linking social preferences and cooperation behavior. To pursue this objective, we systematically examine whether information search effort and weighting are driven by social preferences when people contemplate strategic decisions. In order to particularly capture the temporal dynamics of strategic decision making, we will employ a process measure approach utilizing eye-tracking.

Social preferences in strategic interactions

When observing decision makers in strategic interactions, we often see a wide range of responses. It has been shown that these inter-individual decision making differences are linked to different motives and stable sets of personal preferences (e.g., Messick & McClintock, 1968). One construct that is particularly relevant within the context of strategic cooperation, is social preferences (e.g., Fehr & Schmidt, 1999). Depending on individual social preferences, people vary in the weight they attach to the outcomes they receive themselves and the outcomes allocated to other people (Liebrand & McClintock, 1988). Since outcomes are not decided single-handedly, but instead conditional on the decisions of others, the importance and weights of particular outcomes are determined by social preferences, as well as the resulting beliefs about the behavior of others. Depending on what a person expects their counterpart to choose, the subjective importance assigned to the different payoff outcomes varies (Polonio, Di Guida, & Coricelli, 2015).

Aiming to study the emergence and maintenance of human cooperation in strategic settings, game theory provides a unifying theoretical framework – the prisoner's dilemma game. The combined choices within this game determine the payoffs for each player. Here, defection is a dominant individual strategy, but mutual cooperation is preferred over mutual defection. The tension becomes apparent when the preferred choices of each player lead to individual actions resulting in mutual defection, despite the fact that mutual cooperation is more beneficial. With regard to economic decision-making, social preferences have been a reliable predictor of behavior in experimental games (for a review see Balliet et al., 2009). In strategic settings, prosocial individuals were found to be more likely to cooperate with their partner than individualistic or competitive individuals (Van Lange, 1999). In addition, when receiving information about the partner's behavior before their own decision, prosocials acted contingent on their partner's behavior, while less prosocial individuals were not affected by this information (De Cremer & Van Lange, 2001). Further, a recent meta-analysis revealed that prosocials expected more cooperation from others than individualists and claim that expectations partially mediate the relation between SVO and cooperation behavior (Pletzer et al., 2018). It is still unclear, however, what processes underlie the interplay between SVO and the related expectations in driving strategic decisions.

Social preferences and strategic information search

Even though the link between social preferences and strategic decision making has been shown repeatedly, we know little about the underlying processes in these decisions. Investigating the depth of information processing and weighting as well as the importance of particular strategies and outcomes is especially important in order to understand the different motivations driving strategic decisions. Based on previous studies exploring information search in strategic decision paradigms, we know that process measures during information acquisition reflect the participants' level of strategic sophistication (Chen, Huang, & Wang, 2009; Costa‐Gomes, Crawford, & Broseta, 2001; Polonio et al., 2015; N. Stewart et al., 2016). For instance, Wang, Spezio, and Camerer (2010) utilized eye movements to explore underpinnings of strategic considerations in sender-receiver games. Here, attention patterns (i.e., eye movements) indicated beliefs about the choices of others (i.e., their strategy). Additional studies present evidence that people are boundedly rational when searching for information in strategic decision situations. Instead of attending to all payoffs equally, they showed that individuals are mainly interested in their own payoffs for unilateral defection (i.e., temptation) and payoffs for mutual cooperation (Devetag, Di Guida, & Polonio, 2016; Hristova & Grinberg, 2005). This work reveals that information is systematically weighted within the decision process, but fails to investigate the inter-individual differences in social preferences, which are crucial for the respective importance of particular outcomes as well as strategies.

First studies provided evidence that social preferences not only predict decisions, but also the related decision processes (Camerer, Johnson, Rymon, & Sen, 1993; Fiedler et al., 2013; Jiang et al., 2016; Kieslich & Hilbig, 2014). More evidence comes from the fMRI literature, which showed different neural activations in strategic settings that are driven by SVO (Emonds, Declerck, Boone, Vandervliet, & Parizel, 2011). By focusing, for example, on the effort people exert during information search, Fiedler et al. (2013) have offered important insights into the motivational drivers underlying social preference choices. Analyzing information search in the context of a public-goods game, they show that individualists invest considerably less effort in understanding the decision situation and make often quick decisions to free ride on the cooperation of others. Their results are in line with other research showing similar effects in decomposed dictator games (Dehue et al., 1993; Liebrand & McClintock, 1988). These speak to the functional form of the underlying utility function within such decisions. Specifically, they indicate that individualists take less time to make their decision because they predominantly focus on own payoffs, while prosocials weight and integrate their own as well as the others' payoffs within their decisions. Based on these findings, we assume to observe similar differences in information search effort driven by social preferences in strategic settings. Yet, it should be noted here that under strategic considerations, understanding the payoff structure of the counterpart is also relevant for one's own payoffs, since they are conditional on each other (N. Stewart et al., 2016).

Using gaze patterns to study the weighting of one's own and the other's payoffs in more detail, previous findings show that depending on their SVO, attention directed to other's payoffs differs. Specifically, prosocial individuals were more likely to attend to other's payoffs than individualists in simple money allocation tasks (Fiedler et al., 2013). From this literature, we expect prosocial individuals also to direct more attention towards the other's payoffs when facing a prisoner's dilemma. Again, we point to the strategic decision structure as a caveat, which increases the importance of understanding the other's payoffs in addition to one's own payoffs. Considering that prosocials are more likely to expect their matched partners to cooperate, this belief should reflect in an increase of attention to the cooperative strategy.

Therefore, we hypothesize that prosocial individuals are more likely to invest more effort in their search for information (H1), direct their attention to the other player's payoffs (H2), and direct their attention to payoffs related to the cooperative strategy (H3).

Gaze bias in strategic decisions

Going beyond correlational evidence, various studies have shown that the link between preferences and cognitive processes, in particular attention, is not unidirectional. Instead preferences arguably guide attention, and in turn, attention guides the final decision. This bidirectional link between attention and preference is referred to as the gaze cascade effect (Shimojo et al., 2003). Several studies have demonstrated a gaze bias towards the eventually chosen option (Atalay et al., 2012; Bird et al., 2012; Fiedler & Glöckner, 2012; Glaholt & Reingold, 2009; Nittono & Wada, 2009; Schotter, Berry, McKenzie, & Rayner, 2010). Since N. Stewart et al. (2016) showed evidence for this phenomenon in strategic choices also, we hypothesize that prosocials will increasingly fixate the cooperative strategy, while individualists will increasingly fixate the defective strategy (H4).

Taking a closer look at the attentional feedback on choice, few studies have suggested that the order in which information is attended and integrated is influential on the final decision (e.g., Iliev et al., 2009). In particular, research on primacy effects found that information encoded at the beginning of the decision process was more likely to be remembered (Murdock Jr, 1962) and had a stronger influence on the valuation of goods (Johnson et al., 2007). Additionally, in risky choices, options that were fixated first were more likely to be chosen subsequently (Manohar & Husain, 2013). Formalizing these findings, Johnson et al. (2007) proposed the conceptual framework of the query theory. This theory argues that the first query results in a richer and more heavily weighted representation than the second. We respectively hypothesize that choices will be influenced by the starting point of information search (H5).

The present study

The current study takes a fully incentivized process measure and economic game approach to identify the cognitive channels linking social preferences and cooperation behavior. With the present investigation, we contribute to the literature by systematically testing whether information search effort and information weighting (i.e., attention directed to other's payoffs) are driven by social preferences during strategic contemplations. Testing information search effort during individuals' strategic considerations by measuring the number of fixations and decision time, we gain insights into the individual differences in the depth of processing necessary to make the decision (Bettman et al., 1993). In addition, our aim is to enhance existing knowledge on whether decision differences are purely driven by the level of strategic contemplation or whether they are potentially linked to a qualitative shift in beliefs. To do so, we investigate the proportion of attention towards specific decision strategies and payoffs, since this measure has been shown to quantify the relative importance or weight of a piece of information (e.g., Russo & Leclerc, 1994). Studying these underlying processes offers a deeper understanding of the individual motivations and considerations that drive strategic decision making.

In addition to individual differences, we aim to uncover whether the relation between attention and other-regarding choices goes beyond a correlational link. Particularly, we estimate a gaze bias to eventually chosen options and test how the order in which information is attended to influences strategic choices. By manipulating where people start to search for payoff-related information, this study contributes to understanding how contextual variation influences people's choices in a prisoner's dilemma.

Method

Participants

Participants (all normal or corrected to normal vision, signed informed consent) from the Max Planck Decision Lab subject pool (mostly students of the University of Bonn) were recruited via *Orsee* (Greiner, 2015). The experiment was the second in a two-study experimental battery lasting about 45 minutes.[16] Both experiments were independent and choices within the presented experiment were fully incentivized (average payoff: 9.30 €). We had the financial means to collect data from 100 participants. Hence, 100 participants were scheduled for participation. Due to no-shows and cancellations, 78 participants eventually took part in the study. We excluded trials where more than 40% of the fixations were not directed at any of the predefined AOIs (16.58%, *n* = 4), outliers regarding decision time (4.97%) and participants with a competitive SVO (*n* = 1) from any analyses, resulting in a final sample of 73 participants (mean age = 23.44 years, 63.01% female). The mean SVO angle of the final sample was 19.24° (*SD* = 17.46°).

Materials

SVO ring measure. Participants completed the SVO ring measure online at least 12 hours before coming to the Decision Lab. The instrument is frequently used to determine individual social preferences, i.e., weighting of one's own payoffs and those of others. Specifically, participants were asked to make 24 choices between two options representing money allocations that differed in terms of payoffs for oneself and others. Participants could either maximize their own payoff or decide to forego money in order to benefit the other. The work in this area typically differentiates between people seeking to enhance the outcomes of others (altruists), those seeking to enhance joint outcomes and equality in outcome (cooperators), those seeking to enhance their own outcomes (individualists), and those

[16] The other independent study investigated in a within-design the influence of time pressure and cognitive load on social preferences.

seeking to enhance their own outcome compared to their partners (competitors). Following the literature, individuals with an angle above 22.5° are referred to as *prosocial* types (n = 31) and individuals with an angle below 22.5° are referred to as *individualistic* types (n = 42).[17] Participants' choices were fully incentivized such that one of the money allocations was randomly selected and paid out at the end of the study.

Prisoner's dilemma. In a prisoner's dilemma, two players decide between a cooperative and a defective strategy. Mutual cooperation leads to reward R, whereas mutual defection leads to punishment P. The other two possibilities occur when one player cooperates and the other defects, for which the associated game payoffs are S (sucker's payoff) and T (temptation) for the cooperator and the defector, respectively (Rapoport & Chammah, 1965). Table 3 shows the general form of a symmetric two-person prisoner's dilemma. If the following inequalities are satisfied, a situation can be defined as a prisoner's dilemma: $T > R > P > S$ and $2R > T + S > 2P$. As R, P, T and S vary the situational change is likely to affect the player's behavior (cooperation index):

$$Cooperation\ index = \frac{(R - P)}{(T - S)}$$

Keeping other payoffs constant, cooperation becomes more likely if R and S increase and becomes less likely if T and P increase (Rapoport & Chammah, 1965). The cooperation indices of the prisoner's dilemmas varied between .09 and .5.[18]

Within the experiment, participants were randomly assigned to complete the prisoner's dilemma as the row player (see "Person 1" in Table 3), choosing between top and bottom or the column player (see "Person 2" in Table 3), choosing between left and right. Further, the position of the different strategy combinations was varied between subjects such that pressing *A* on the keyboard sometimes indicated a cooperative choice and at other times indicated a

[17] See Figure S5 in the supplement for the distribution of participants' SVO angles.
[18] For a list of the games used and their respective cooperation index, see Table S10.

defective choice. This variation allowed for a counterbalanced presentation of the different strategy combinations and subsequent eye-tracking analyses.

Table 3

General form of a 2-person symmetric Prisoner's Dilemma

	Person 2	
Person 1	Cooperation	Defection
Cooperation	*R, R*	*S, T*
Defection	*T, S*	*P, P*

Note. The payoff to the left of the comma in each cell is Person 1's outcome; Person 2's outcome is to the right of the comma. *R* indicates reward for mutual cooperation, *S* indicates sucker's payoff, *T* is temptation to defect, and *P* is punishment for mutual defection.

Procedure

At least 12 hours before taking part in the experiment, participants completed an online version of the SVO questionnaire (Liebrand & McClintock, 1988), determining their social preferences. Upon arriving at the lab they were seated in front of a computer screen (17" color monitor with a native resolution of 1280×1024 pixels), received written instructions of the prisoner's dilemma and the search task used for location cueing and were calibrated to an Eyegaze remote binocular system (LC Technologies) with a sampling rate of 120 Hz and an accuracy of about 0.45°. Viewed from a distance of 60 cm, the screen subtended a visual angle of 39° horizontally and 28° vertically. A chin rest was used to ensure data quality by reducing head movement during the experiment. Following a 9-point calibration procedure on a grey background, participants were instructed in a simple search task used to cue particular locations and the respective strategies that were presented at the same coordinate in the next step. The search task manipulation was used in order to direct participants' attention to a specific area of the screen (location cueing; Wright & Ward, 2008) and set a cooperative or defective reference point at the start of the decision making process. Within the task, participants had to identify a picture that did not match the presented set of 9 pictures by pressing *A* on the keyboard when the mismatch was presented on the left side of the screen, and by pressing *B* when it was presented on the right side. For example, if there are 8 pictures of rodents and 1 picture of a bird on the left side of the screen, the picture of the bird does not match the others and the correct response would be to indicate the left side by pressing *A*. After participants had logged their answer, the payoff matrix of a prisoner's dilemma appeared and they were asked to choose to cooperate or defect. The two decision options of the prisoner's dilemma were labeled as *A* and *B,* and participants were asked to indicate their choice of strategy by pressing *A* or *B* on the keyboard. Participants did not receive any feedback regarding the other player's choice.

Overall, participants completed 10 trials consisting of the presentation of a central fixation cross (500 ms), followed by a search task and a prisoner's dilemma (see Figure 9). After they had completed all trials, they received a payoff determined by a randomly drawn choice in the prisoner's dilemma and a debriefing. All stimuli were presented via NBS Presentation®. For all materials, original instructions and the experimental program, see bit.do/Strategic_Material.

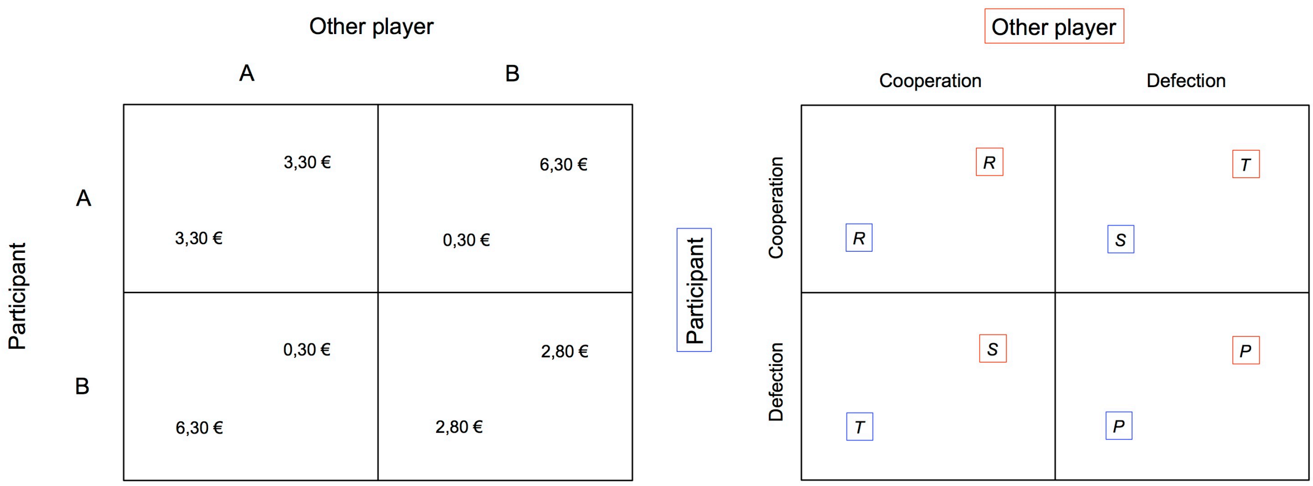

Figure 9. Example of a prisoner's dilemma. Participants have the choice to cooperate or defect, which determines their payoff, depending on the other player's choice.

RR = Mutual cooperation, TS = Temptation, ST = Sucker, PP = Mutual defection.

Data Preparation and Pre-processing

The eye-tracking and choice analyses were performed using custom STATA 14 scripts (find the raw data and complete data pre-processing script here bit.do/Strategic_Data). The raw data were pre-processed in order to determine saccades and fixations as well delete artefacts in the data. Therefore, the following pre-processing steps were applied (adaptation from Salvucci and Goldberg (2000)): (1) fixations were defined as relative stable gaze (raw data points are located with a radius of 30 pixel) which lasted at least 50 ms, (2) blinks were removed and (3) trials were excluded in which 40% or more of the fixations were located outside of the predefined AOIs (16.58%) and (4) to account for outliers, trials that were very short (< 200 ms) or very long (> 3 standard deviations of the mean) were excluded from the analysis (4.97%).

Overall, eight non-overlapping areas of interest (AOIs) were defined, containing the payoffs connected with the different choices of the participant and her matched partner (100×100 pixels, mean margin of 25×20 pixels). Other AOIs included text labels for the payoff matrix, which were not included in the analysis. We constructed the stimuli such that the distance between objects and the AOI margin was maximized, following suggestions by Orquin et al. (2016).

SVO, type of choice (cooperation vs. defection) and location cue were used as predictors in repeated measures logistic regressions with a random effects model and robust standard errors. Controlling for any learning effects across time, trial number was included as a control variable in all models. Another factor influencing strategic choices is the relation between possible payoffs for mutual cooperation relative to possible gains from defecting (cooperation index; Terhune, 1968). To account for characteristics of the task, cooperation index was also included as a control variable in all models.[19] In case an interaction effect was included in the model, all variables were centered. The results of the Shapiro-Wilk test showed support for a skewed distribution of response time ($W = 0.73$, $z = 11.39$, $p < .001$) and fixation number ($W = 0.73$, $z = 11.45$, $p < .001$). Consequently, both variables were log-transformed for all analyses. For the final data set and the complete analysis script, see bit.do/Strategic_Analysis.

[19] Including control variables has no substantial influence on the main analyses. For analyses without control variables, see the supplementary material.

Results

Strategic choice behavior

Overall, 56.61% of the choices individuals made in the prisoner's dilemma were cooperative. Replicating previous findings, prosocial participants made 19.36% more cooperative choices than individualists. Specifically, as participants' SVO angle increased the likelihood of making a cooperative choice significantly increased (OR = 1.06, $z = 3.41$, $p = .001$). Additionally, in line with previous findings, making a cooperative choice became more likely as the cooperation index of a game increased (OR = 68.84, $z = 5.87$, $p < .001$) and hence was used as a crucial control within the process analyses.

SVO and information search

Information search effort. To analyze the underlying processes of strategic choices, specific measures were selected to provide insights into the depth of information search, namely decision time and the number of fixations. On average, prosocial individuals took 7.3 seconds to make their choices, while individualists took slightly longer at 7.5 seconds. Contrary to H1 and findings in non-strategic decision environments, SVO did not have a significant effect on decision time or the number of fixations (Table S12).

Information weighting. For a more detailed understanding of participants' weighting process, the influence of SVO on relative attention directed to participants' own payoffs as compared to the other players' payoffs was examined. Overall, participants were less likely to look at their own payoffs than the other player's payoffs (43.45%). While prosocials directed 45.08% of their attention to the others' payoffs, individualists directed 42.22% to them. In line with H2, more prosocial participants were significantly more likely to attend the other players' payoffs than individualists ($\beta = .21$, $z = 2.56$, $p = .011$).

Adding further to the understanding of underlying processes, the proportion of attention directed to specific strategies was examined (H3). The results show that, on average, prosocials directed 52.45% of their attention to outcomes associated with cooperation (mutual cooperation and sucker's payoff), while individualists directed 48.47% of their attention to these outcomes. This difference is statistically significant, with prosocials being more likely to direct their attention towards cooperative strategies than individualists (β = .20, z = 2.94, p = .003). Investigating attention to the specific outcomes in more detail, Figure 10a illustrates that as SVO increases, the proportion of attention to the potential payoffs of mutual cooperation (RR) increased, while attention towards the other payoff combinations slightly decreased. This effect is driven by prosocial individuals who decide in line with their prosocial preference and cooperate. No such attentional focus to a specific outcome combination can be observed for prosocial individuals who go against their original inclination to cooperate. Using SVO to predict attention directed to mutual cooperation in cooperative choices, we do not find a significant link (OR = 1.003, z = 0.50, p = .615); and neither for a relation between SVO and attention directed to temptation payoffs in defective choices (OR = 1.01, z = 0.69, p = .490).

Temporal dynamics. Taking a closer look at the allocation of attention, we examined the temporal dynamics of attention during the complete decision making process. The results reveal an increase of proportion of attention towards the chosen option over time (i.e., gaze cascade effect). Particularly, we tested whether individual social preferences affect the magnitude of a gaze cascade effect by taking SVO into account (H4). The results indicate a successful replication of the established gaze cascade effect with an increase of attention towards the eventually chosen strategy across time (β = 0.08, z = 4.94, p < .001).[20] This effect tends to be stronger for prosocials than for individualists (β = 0.05, z = 2.64, p = .008).

In a next step, we included only last fixations in the analysis to gain a deeper understanding of the temporal dynamics in strategic decisions. Last fixations are especially relevant as they are a stronger predictor of choices than previous fixations (Krajbich et al.,

[20] For all temporal analyses, we excluded first fixations to eliminate the exogenously directed fixations due to location cueing.

2010). Taking into account only last fixations before making a choice, attention patterns become more pronounced (see Figure 10b). Prosocial individuals who decided to defect mostly directed their attention towards the temptation payoff (39.46%) just before making their choice. For individualists the attention pattern is less clear, with temptation and mutual defection receiving similar proportions of attention.

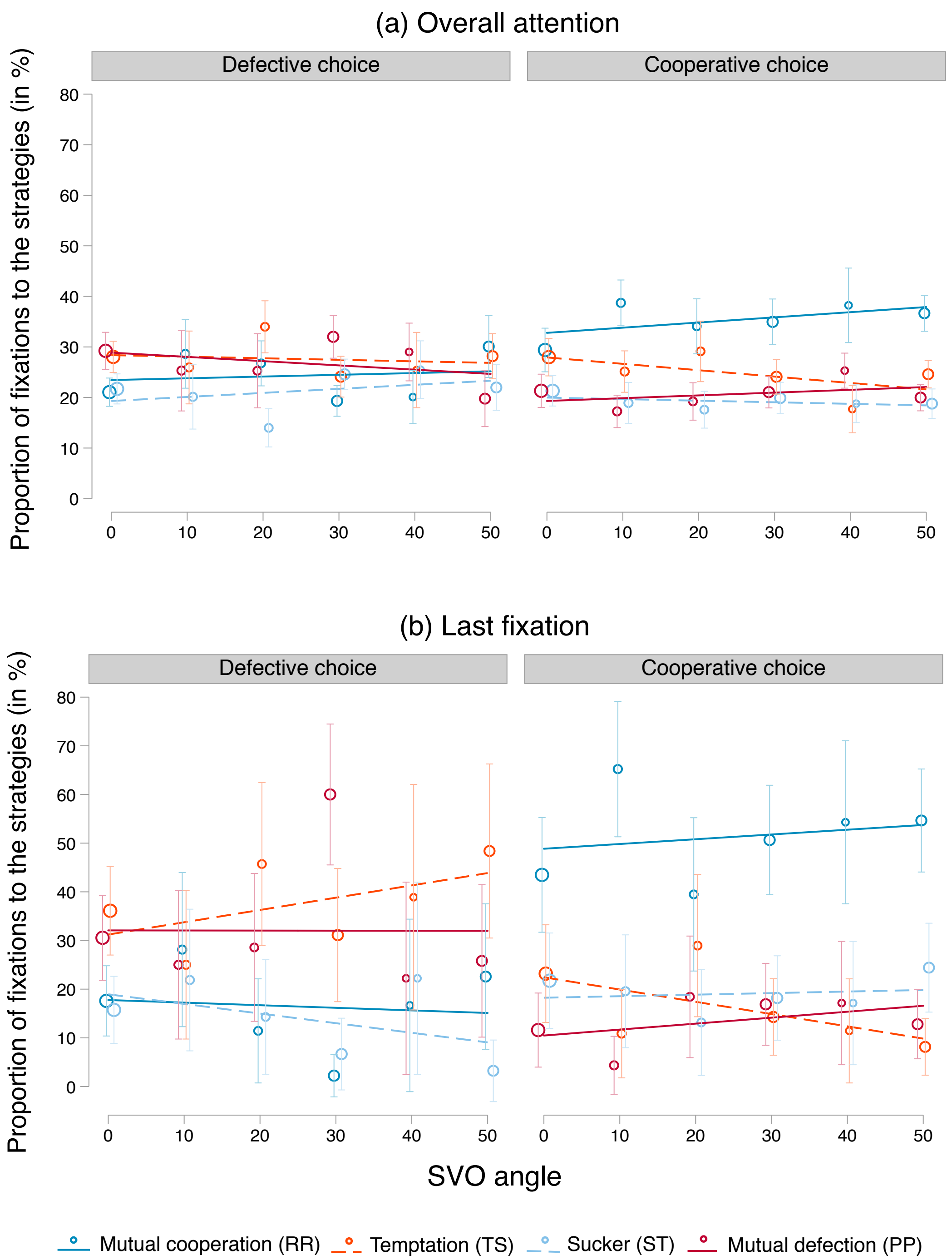

Figure 10. Differences in attention allocation directed to the payoff combinations driven by SVO angle and separately for defective and cooperative choices (error bars indicate 95% confidence intervals and circle size reflects the number of observations).

Type of choice and information search

Information search effort. Investigating the mechanisms driving choices in further detail, we examined in an exploratory set of analyses the way in which cooperative choices differ from defective choices with regard to the depth of information search and attention allocation. Cooperative choices were on average 1.67 seconds faster than defective decisions and presented with 7.22 less fixations during the decision process. To test for differences, the type of decision was used to predict response time and fixation number. The results indicate that cooperative choices are associated with shorter response times (β = -.12, z = -2.89, p = .004) and a smaller number of fixations (β = -.12, z = -2.83, p = .005). The link between type of choice and information search effort differs depending on SVO angle. Specifically, for individualists, the type of choice is a stronger predictor of response times (β = -.12, z = -3.28, p = .001) and number of fixations (β = -.10, z = -2.71, p = .007) than for prosocials.

Information weighting. Next, differences in attention allocation to the varying strategy combinations for cooperative and defective choices were tested for. During cooperative decisions, participants directed on average 52.51% of their attention to cooperative payoff combinations (mutual cooperation and sucker's payoff) while during defective decisions the average was at 46.94%. Using a regression analysis, cooperative choices significantly predict the proportion of attention directed to the cooperative strategy combinations (β = .24, z = 4.92, p < .001).

Temporal dynamics. Analyzing the temporal dynamics, the results indicate that differences in information search prior defective and cooperative choices were mostly driven by attention allocation during the last part of the trial. Specifically, for cooperative choices there was a pronounced increase in attention towards mutual cooperation, decreasing attention to the other strategy combinations (see Figure 11). For defective choices, a similar proportion of attention was directed towards temptation and mutual defection payoffs. Following up on the temporal dynamics analysis, we tested whether the type of choice participants make affects the established gaze cascade effect. The findings reveal that the gaze bias to eventually chosen options does not differ depending on whether a choice was cooperative or defective (β = .001, z = 0.03, p = .976).

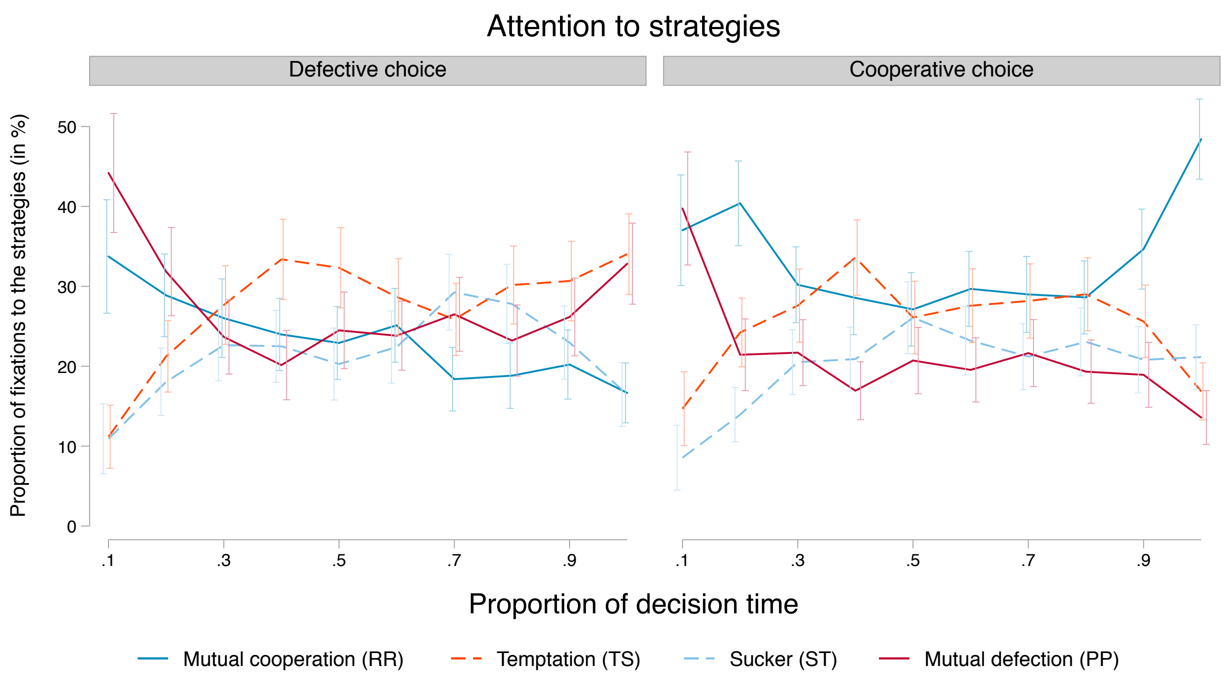

Figure 11. Proportion of attention towards the strategy combinations as a function of relative time passed in the decision making process and the final decision made (defection vs. cooperation). Error bars indicate 95% confidence intervals.

Influence of attentional reference points

Investigating the role of attentional reference points, we first tested the effectiveness of the location cueing manipulation, by calculating the likelihood of the first fixation being on the cued strategy. The manipulation check shows that the first fixation is significantly more likely to be directed towards the cued strategy (OR = 4.76, z = 5.36, p < .001). Overall, we observed an average increase of 7.59% in attention directed towards payoffs presented in previously activated locations (see Figure S2). Yet in contrast to H5, there is no evidence that location cueing influenced the subsequent decision (OR = 0.96, z = -0.20, p = .840).

Discussion

The present study investigates attention patterns in strategic choices using eye-tracking thereby extending the existing research on the underlying cognitive mechanisms in social dilemmas. Overall, the findings suggest that social preferences are an important driver of strategic considerations and reflect in eye movements. Uncovering differences in information weighting, we show that prosocial individuals were more likely to direct their attention to the other player's payoff and the cooperative strategy than individualists. In contrast to findings in simple games, information search effort was not affected by individuals' SVO. Using the type of choice to predict information search, cooperative choices were associated with shorter information search and increased attention to the cooperative strategy than defective choices. Taking temporal gaze patterns into account, our results successfully replicate the gaze cascade effect in strategic decisions with an increase of attention to the chosen strategy across time and additionally show that this effect tends to be stronger for prosocial individuals.

Information search effort in strategic environments

Exploring the underlying drivers of cooperation in more detail, the present study utilized eye movements to uncover individuals' strategic considerations. Notably, a comprehensive analysis is offered by using a number of dependent variables such as decision time, fixation number and proportion of attention. In contrast to the current study, previous research found that a prosocial value orientation was associated with longer decision times when compared to individualists (Dehue et al., 1993; Fiedler et al., 2013; Liebrand & McClintock, 1988). Arguably, the strategic component of the situation diminishes differences in the extent of information search between prosocials and individualists. Due to the additional complexity and dependency of own outcomes on others choices, more extensive computations are required in strategic environments (Rapoport & Chammah, 1965). For individualists, the amount of information that is relevant for their decision increases, because in interdependent situation it is necessary to assess both, own and other's outcomes, in order to choose the strategy resulting in the best outcome for themselves. Thus, by taking other's outcomes into account as well, individualists' information search process is more similar to prosocials' search for information. The similarity in information search effort between prosocials and individualists suggests that, rather than avoiding search effort in general, individualists search rationally for information that is important for their decisions. It also suggests that besides individual differences, the decision structure of the social dilemma has an important influence on information search effort. Building upon this finding, one interesting avenue for future research would be to compare the extent of information searches in strategic vs. non-strategic environments in order to systematically investigate the influence of the decision structure on information search effort.

Additionally, the results revealed systematic differences in information processing between cooperative and defective choices. In line with previous research on cooperation and decision time defective choices were associated with more extensive information search than cooperative choices (e.g., Rand, Greene, & Nowak, 2012; but see e.g., Tinghög et al., 2013). Other findings indicate that this only holds for individuals who decide in line with their initial social preference (Mischkowski & Glöckner, 2016). The current findings revealed that social preferences affect the strength of the link between cooperative/defective choices and information search effort. These results suggest that cooperative and defective choices are related to different evaluation processes that are linked to individual social preferences and reflect in decision time.

Attention patterns reflect strategic considerations

Going beyond the extent of information search, our results are in line with results on information weighting in money allocation tasks where prosociality was related to more fixations to the outcome of others (Fiedler et al., 2013). A similar notion was supported by

Kurzban and DeScioli (2008) who assume that participants seek the information that is most relevant to their contribution strategy. Their findings indicate that information search differed depending on whether participants' decided to reciprocate or free ride. The present results show that prosocials direct more attention to the other player's payoffs and thereby suggest that prosocials weight outcomes for others more strongly than individualists when making strategic decisions. Even though they invest similar effort in their information search, the systematic differences in weighting suggest that social preferences are associated with different decision strategies. Such strategies are supposedly similar across decision contexts as we find that prosocials overweight other's payoffs in both, strategic and non-strategic situations.

These findings have relevant theoretical implications. The bounded rationality framework proposed that decision processes are limited by individual information processing. The results reported here support this notion by showing that attention allocation is driven by individual preferences and corresponds to the motives each individual pursues. This is consistent with evidence showing that players selectively attended to information that is relevant to them (Hristova & Grinberg, 2005), in particular their own payoffs (Devetag et al., 2016). Further, the current findings suggest that models formalizing strategic thinking (e.g. level-k) could predict strategic considerations more accurately by taking individual social preferences into account.

Temporal dynamics

The results on temporal dynamics successfully replicate evidence for the previously established gaze cascade effect (Armel et al., 2008; Fiedler & Glöckner, 2012; Krajbich et al., 2010; Shimojo et al., 2003; N. Stewart et al., 2016). We contribute to the respective literature by taking an individual differences perspective to understand the temporal and motivational dynamics of strategic decision making and present evidence that the gaze bias is stronger for prosocials than for individualists. These differences suggest that depending on their social preferences, individuals' decision process is qualitatively different, with more prosocial individuals showing higher levels of motivated information search, which has been linked to experiencing less uncertainty during the decision process (De Dreu, Nijstad, & van Knippenberg, 2008). Further investigations of this link between social preferences and decision uncertainty would be valuable for understanding the extent to which choices in social situations can be influenced by exogenously interrupting the decision process.

Strategic choice behavior

In addition, the results presented here succesfully replicate strategic cooperation behavior on two accounts successfully. First, SVO has been found to be a reliable predictor of cooperation behavior with more prosocial individuals cooperating more than less prosocial individuals. This finding is in line with the results of a meta-analysis by Balliet et al. (2009), which established a robust link between SVO and cooperation in social dilemmas (see also Bogaert et al., 2008). Second, as the cooperation index of a game increased cooperation became more likely, which is consistent with previously reported evidence (Goehring & Kahan, 1976; Rapoport & Chammah, 1965; Terhune, 1968). This fortifies the suggestion that an increase of the reward for joint cooperation and of the punishment for joint defection in relation to a decrease in the temptation to defect and the sucker's payoff leads to higher rates of cooperation.

Evaluation of attentional reference points

The failed influence of location cueing on choice behavior stands in contrast to research on query theory highlighting the weight of first queries (Johnson et al., 2007) and findings in risky choices, showing that first fixated options are more likely to be chosen (Manohar & Husain, 2013). To carve out the specific differences between simple and strategic decisions, it will be necessary to understand the impact of information order within decision making. Developing a search task, which was used prior to the choice task in order to avoid obviousness and resulting demand effects, we provide a new tool to systematically investigate these order effects. As other studies mostly integrated the manipulation of attention into the choice task, the separation of the two possibly leads to an attenuation of the location cue. To understand strategic contemplations, studying decision processes in prisoner's dilemmas is an important step. Information search requires more resources in these situations than in simple non-strategic choices (Rapoport & Chammah, 1965). The strategic structure of the environment supposedly prevents a spillover of manipulating attention to subsequent choices. Investigating the extent to which attention can influence choices in social dilemmas, it is important to understand how dynamic individual social preferences are. With previous research showing that social preferences are a stable over time (Carlsson et al., 2014), it is questionable whether such preferences can be influenced via attention. These limitations call for a critical test of previous causality claims regarding eye gaze and choice behavior.

Conclusion

In conclusion, social preferences are able to explain systematic differences in strategic information search. Attention patterns reflect weighting processes associated with individuals' SVO angle and individuals' final choice. Uncovering some of the strategic contemplations people are facing in social dilemmas, temporal dynamics show that attention allocation unfolds differently for cooperative and defective choices. These findings contribute to research on social dilemmas as they shed light on the impact of social preferences on strategic information search and develop a preliminary understanding of the underlying drivers of cooperation and defection.

Chapter III

The power of attention:

Using eye gaze to predict other-regarding and moral choices

Minou Ghaffari [a, b] & Susann Fiedler [a]

[a] Max Planck Institute for Research on Collective Goods

[b] University of Zurich

This article was accepted for publication in *Psychological Science*.

Abstract

According to research studying the processes underlying decisions, a two-channel mechanism connects attention and choices: top-down and bottom-up processes. To identify the magnitude of each channel, we exogenously varied information intake by systematically interrupting participants' decision process in Study 1 ($N = 116$). Results show that participants were more likely to choose the pre-determined target option. Since selection effects limited the interpretation of the results, we used a sequential presentation paradigm in Study 2 (pre-registered, $N = 100$). To partial out bottom-up effects of attention on choices, in particular, we presented alternatives by mirroring the gaze patterns of autonomous decision makers. Results revealed that final fixations successfully predicted choices when experimentally manipulated (bottom-up). Specifically, up to 11.32% of the link between attention and choices is driven by exogenously guided attention (= 1.19% change in choices overall), while the remaining variance is explained by top-down preference formation.

Keywords: bottom-up, top-down, eye-tracking, social preferences, moral decision making

Introduction

Walking down the street, a stranger struggles with her grocery bags. When considering whether to help her, the cost of your time and physical effort are weighed against the benefit for the stranger. Thus, personal self-interest is in conflict with what is best for someone else. Does the timing of asking what you want to do about this situation alter your subsequent choice? Recently, a number of studies have used gaze recordings to understand the processes underlying decision making in different areas (for a review see Orquin & Mueller Loose, 2013). So far, they have provided consistent evidence for a correlation between eye gaze and subsequent other-regarding (e.g., Fiedler, Glöckner, Nicklisch, & Dickert, 2013), moral choices (Pärnamets et al., 2015), consumer choices (e.g., Ashby, Walasek, & Glöckner, 2015; for a review see Krajbich & Smith, 2015), attractiveness ratings (e.g., Shimojo, Simion, Shimojo, & Scheier, 2003; Störmer & Alvarez, 2016), and risky choices (e.g., Fiedler & Glöckner, 2012). The current state of the evidence suggests that both top-down preferences and characteristics of choice presentation drive information search. Inspired by these findings, the current studies aimed to disentangle these two drivers of the correlation between eye gaze and choice behavior. In doing so, we critically tested the causality claims made in recent publications (Armel, Beaumel, & Rangel, 2008; Milosavljevic, Navalpakkam, Koch, & Rangel, 2012; Pärnamets et al., 2015; but see Newell & Le Pelley, 2018) in two high-powered, eye-tracking studies using eye gaze to predict other-regarding and moral choices.

Choice behavior and visual attention

Many of the assumptions concerning the link between eye gaze and choice behavior are based on the attentional drift-diffusion model (aDDM; Krajbich, Armel, & Rangel, 2010). The aDDM is an evidence accumulation model that assumes that directing eye gaze towards a specific option resembles the process of collecting evidence in favor of that option. Considering the initial example of helping a stranger carry grocery bags, evidence accumulation models would predict that the decision to help is made by accumulating stochastic information over time until the net evidence in favor of one alternative exceeds a pre-specified threshold and a decision is made. Another key idea of the aDDM is that fixations affect the value comparison process by introducing a temporary drift bias towards the fixated item in the positive domain. More precisely, fixations supposedly have a causal effect on the value comparison process.

The theoretical assumptions of the aDDM highlight the importance of the two relevant factors when studying the link between attention and choice behavior: (1) proportion of attention directed towards stimuli and (2) the direction of the last fixation. Pärnamets et al. (2015) aimed to understand this interplay and subsequently developed a gaze-contingent paradigm. In doing so, they showed a significant correlation between the direction of the last fixation as well as a positive (but not significant) effect of the relative overall fixation time of an option (i.e., relative time advantage) on moral choices. The authors subsequently concluded that there is a causal link between last fixation and moral choices. However, only the relative time advantage was manipulated experimentally, whereas the direction of the last fixation was simply observed in the data.

Across two studies, we tackled the remaining question of causality by developing the experimental paradigm further so that the causal link between the last fixation and subsequent choices could be tested directly. To do so, we systematically interrupted decision makers' decision process based on their gaze behavior to assess the impact of attention on choices.

Construction of other-regarding and moral choices

Within this investigation, we focused on two domains: other-regarding and moral choices. Studying the link between attention and choices in these contexts is particularly interesting because it allowed us to explore the similarities and differences between decisions involving social vs. moral concerns. While social (other-regarding) dilemmas involve strategies that differ in terms of social desirability (e.g., common gain vs. self-interest), moral dilemmas involve situations in which all possible solutions are associated with undesirable outcomes. In both domains, at least two possible options stand in conflict with each other. While classic economic theories for example suggest that people try to maximize their own welfare in other-regarding problems, research has shown that a substantial proportion of people are willing to sacrifice their own benefits because they weight also the benefits of others in their decision process (Fehr & Schmidt, 1999). The necessary weighting process and its link to heterogeneous underlying preferences make other-regarding and moral problems especially interesting for the study of decision making.

Even though the motives for both decisions often overlap, both decision environments are also distinct. While other-regarding choices are a fairly regular element of day-to-day life, moral decisions are less frequent and often discussed more abstractly. Consequently, it is important to include both domains when studying underlying attentional processes.

Most research discusses social and moral preferences as stable constructs (Alger & Weibull, 2013; Carlsson, Johansson-Stenman, & Nam, 2014) that strongly influence behavior (Balliet, Parks, & Joireman, 2009). Yet, findings showing that even slight changes in the representation of moral and social problems such as the presentation order or format altered decisions (Haley & Fessler, 2005; Iliev et al., 2009; Knez & Camerer, 1995) indicate that people's preferences are not completely stable and instead are partly constructed during the decision making process through bottom-up processes (Sharot, Velasquez, & Dolan, 2010; Simon & Spiller, 2016).

Overall, these findings indicate that choices are driven by a two-channel mechanism that includes top-down and bottom-up processes. Going beyond previous studies, the current design enabled us to disentangle the relative contribution of these two channels on other-regarding and moral choices by using eye gaze as an indicator of choices processes. Study 2 extended this first investigation by utilizing a decision paradigm that allowed to fully control information intake though exogenously provided real-time viewing patterns. It coalesced Study 1 as it disentangled bottom-up processes from top-down processes and avoided potential selection effects.

Study 1

Study 1 focuses on three key points: First, we aim to disentangle top-down and bottom-up processes of decision making. Second, we will test whether the effect of attention on choices is context-dependent by comparing other-regarding and moral choices. In order to ensure that effects can be attributed correctly to one or the other channel, we will systematically examine the data concerning potential selection biases.

Method

Participants. One hundred and twenty participants (mean age = 22.9 years, 55.6 % female, all normal or corrected to normal vision) from the Max Planck Decision*L*ab subject pool (students of the University of Bonn) were recruited via Orsee (Greiner, 2015). The experiment, which required approximately 30 minutes to complete, was the first in a two-study experimental battery lasting a total of approximately 60 minutes (the second unrelated study was designed by a different experimenter). Participants received a fixed payoff of 6 € for the present study. All participants signed a consent form for taking part in experimental studies and were debriefed after the experiment. Based on the effect size reported by Pärnamets et al. (2015), we estimated a minimum sample size for this study of approximately 80 participants. Due to joint data collection for multiple experiments, we had the opportunity to collect data from 120 participants. Hence, this sample size was set as the stopping point for data collection. We excluded four participants who either reported difficulties hearing the recordings or did not understand the control questions.

Materials and Procedure. Participants completed the Social Value Orientation (SVO) Ring Measure online at least 12 hours prior to taking part in the experiment (Liebrand & McClintock, 1988). The instrument is frequently used to determine individual social preferences – i.e., the weights they attribute to their own and others' payoffs. Specifically, participants were asked to make 24 choices between two options representing money allocations that differed in terms of payoffs to themselves and others. Participants could either maximize their own payoff or sacrifice their personal gain in order to benefit others. While typically individuals attributed greater weight to their own payoffs they did not ignore others' payoffs completely (Liebrand & McClintock, 1988). According to their choices, participants were classified as either cooperative (SVO angle < 67.5° and > 22.5°) or individualistic (SVO angle < 22.5° and > -22.5°). Their choices were fully incentivized in that one of the money allocations was selected at random and paid out with real money. We deliberately did not pay out all 24 choices in order to prevent hedging behavior.

Upon arriving at the lab, participants were seated in front of a computer screen (17" and 14" color monitors with a native resolution of 1280 × 1024) and were calibrated to an Eyegaze system (LC Technologies) with a remote binocular sampling rate of 120 Hz and an accuracy of about 0.45˚. Viewed from a distance of 60 cm, the screen subtended a visual angle of 28° horizontally and 21° vertically. A chin rest was used to ensure data quality by reducing head movement during the experiment. Following a 9-point calibration procedure on a grey background, participants read the instructions on the screen. Participants were presented with 90 statements via headphones. These recordings included descriptions of situations in which personal interests stood in conflict with other's interests (other-regarding) and moral issues as well as general knowledge questions (factual). The set of other-regarding recordings included statements such as "If I saw a stranger on the street struggling with her grocery bags, I would help her carry them". In response to this statement, two alternative choice options appeared on the screen ("Only if I have time" and "I would usually help"). Participants were instructed to listen carefully to the recording and then choose the alternative they considered to be most in line with their preferences. Following their choice, they were asked whether they had been able to see the two alternatives (yes vs. no), how confident they were regarding their answer (7-point Likert scale), and how important the related topic was to them (7-point Likert scale). The trial then continued with the next recording.

Eye-tracking paradigm. To test whether the direction of the last fixation has a causal influence on choices, we developed a novel paradigm based on the method used in Pärnamets et al. (2015). We adapted the gaze-contingent paradigm such that the decision prompt was sent conditional on the fixation location and absolute time spent on each of the options (see Figure 12). Specifically, participants were prompted to choose when their last fixation was directed at the randomly allocated target option and both options had been attended to. Within our experimental program, three decision prompt criteria were implemented. First, to ensure that participants knew both choice alternatives: (1) the target alternative had to be attended to for at least 750 ms and (2) the nontarget had to be attended to for at least 250 ms. When both of these criteria were fulfilled, the decision prompt was sent as soon as (3) the target option was fixated again. In case the process exceeded 3000 ms, the decision prompt was automatically sent to avoid lengthy decision trials. The essential feature that differentiates this paradigm from the one used in Pärnamets et al. (2015) is the addition of criterion (3). Participants were informed that the screen showing the alternatives would be presented for a short and variable amount of time. To ensure that participants were able to make an informed choice even when the presentation time was very short, we asked if they had been able to see the two alternatives after the presentation.

For this study, it was especially important to predefine areas of interest (AOIs) in order to determine the attention towards a specific option and accurately apply the gaze-contingent manipulation. We thus defined two non-overlapping AOIs containing the two different options from which participants could choose (each 320 × 140 pixels with a mean margin of 75 × 30 pixels). The AOIs were vertically centered and horizontally positioned on the far left and far right, respectively.

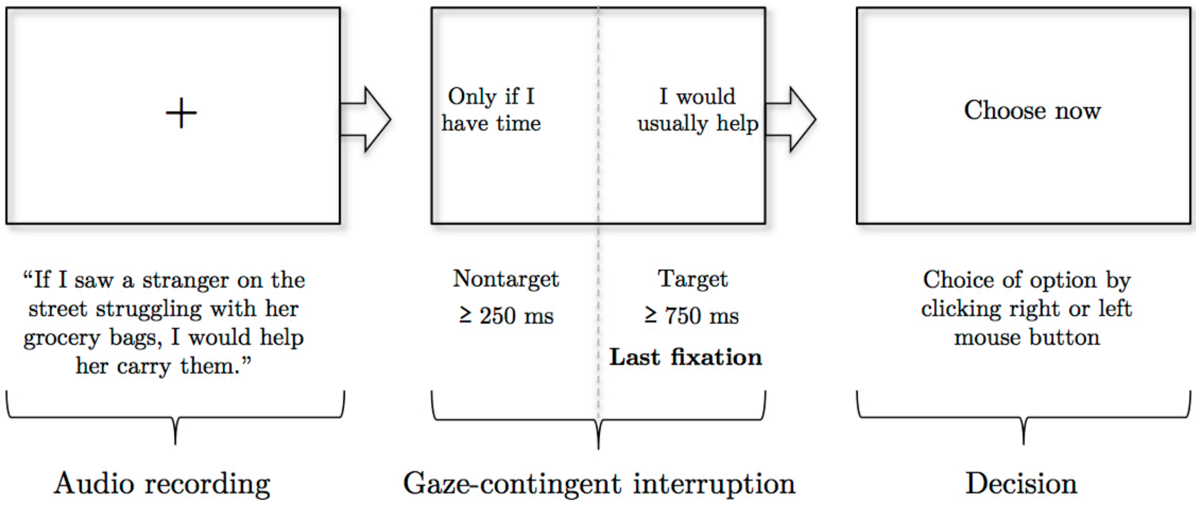

Figure 12. Participants first listened to the recording while a central fixation cross was presented on screen. Following the recording, two options appeared on the screen that were randomly assigned to the right or left side. Participants viewed the alternatives until their choice was prompted, either by fulfilling the decision criteria or after 3000 ms, whichever came first. Participants then made a choice by clicking the right or left mouse button, respectively. After answering questions regarding their perception of the alternatives, confidence, and importance of the topic (omitted from this figure), the next recording was played via the headphones. For presentation purposes, we modified the background color and font color of the stimuli for this figure.

Stimuli. A total of 90 questions were presented via headphones – 30 other-regarding items, 30 moral items, and 30 factual items. The recordings were all read by the same female voice using the Audacity software and had a mean duration of 6.5 s (*SD* = 1.7 s). While listening to the recording, participants viewed a fixation cross at the center of the screen. The order of the questions as well as the screen side on which each answer option appeared was determined randomly. All answer alternatives were matched in terms of visual features including background color of the screen (grey), font type (Arial), font color (white), and font size (17). The presented moral and factual items constituted a subset of the items that were used in Pärnamets et al. (2015). Thirty of the original moral items were selected. Items were excluded if they did not fit to the German student population (e.g., “Acting according to God’s will is key to being moral”). Other-regarding items were constructed using items from the prosocial personality battery (Penner, Fritzsche, Craiger, & Freifeld, 1995), self-reported altruism scale (Rushton, Chrisjohn, & Fekken, 1981), altruistic personality scale, (Rushton et al., 1981), honesty-humility scale of the HEXACO (Ashton & Lee, 2009), and self- and other-interest inventory (Gerbasi & Prentice, 2013). Factual items were used as filler tasks and were therefore excluded from all analyses, following the procedure in Pärnamets et al. (2015). All stimuli were presented via NBS Presentation®. As indicated by their responses to the question “Do you have an assumption what we investigated in this study?”, all participants were unaware of the gaze contingent interruption of their decision making process. For a complete list of items, original instructions, recordings, and the experimental program, see bit.do/osf-Material.

Data preparation. Participants were able to choose an option before the decision prompt was activated (= *self-determined* trials, 37.78% of decisions). Providing the option for self-determined trials enabled us to distinguish between top-down and bottom-up processes by comparing them to trials in which the last fixation was experimentally manipulated (= *interrupted* trials, 43.31% of decisions). Trials were excluded from the analysis if either there was a timeout after 3000 ms (18.92% of decisions) or participants were not able to see both alternatives (0.75% of interrupted choices and 0.20% of self-determined choices). Including these trials in the analyses did not change our findings. To check whether participants followed the instruction of choosing as soon as they were prompted, we analyzed response times after viewing the options (M = 1.58 s, SD = 2.71 s). As this indicates a fairly short response time, we can assume that participants generally followed the instruction to decide right after the decision prompt was presented. The raw data of the study and a script for the pre-processing procedure can be found here bit.do/osf-Data.

Results

All of the following analyses used a repeated measurement logistic regression predicting the final choice by the location of the target (or last fixation) and controlled for relative time advantage, time effects (trial number), and participants' perceived confidence in their answer. Relative time advantage refers to the amount of time in which a participant's gaze focused on the option on the right side minus the amount of time in which his or her gaze focused on the option on the left side (i.e. negative values are possible). We predicted choice of right option rather than target choice. Using last fixation to predict target choice would not be meaningful in this case, because the last fixation is per definition by the program always directed towards the target. Consequently, there is no variation in the predictor variable; and we have perfect collinearity with the constant in our model. By using "option on the right" as the dependent variable and "last fixation to the right" as a predictor, we have the opportunity to test the relationship in which we are interested. When making a large number of sequential choices, familiarity or learning effects often influence the decision process and subsequently choice behavior. Adding time effects allowed us to control for any such influence of time trends on the link between attention and choices. Another factor that has been shown to have an influence on subsequent choices was the relative time advantage towards one of the sides. Thus, we included this variable as an additional control variable. Examining the distribution of attention for interrupted trials showed that in the current adaptation, attention is equally distributed across both target and nontarget options, whereas in the original paradigm participants directed more attention towards the target option (Pärnamets et al., 2015). Due to our interest in the top-down and bottom-up processes involved, we will present separate analyses for interrupted and self-determined trials. For the final data set, the complete analysis script, and additional analyses, see bit.do/osf-Analysis.

Magnitude of top-down and bottom-up mechanisms. Overall, we found a strong correlational link between attention and self-determined other-regarding and moral choices. Specifically, 72.83% of all last fixated alternatives were subsequently chosen (Table 4A). To determine the role of bottom-up processes in the link between the last fixation and subsequent choice, we analyzed trials in which the gaze-contingent paradigm successfully interrupted the decision making process. The results showed that in these trials the last fixated (pre-determined target) option was chosen in 62.02% of decisions (Table 4B). Hence, the attention-choice relationship might be driven by up to 36.40%[21] by the influence of attention on choice. In contrast, the remaining variance cannot be attributed to this bottom-up connection but rather to the fact that attention allocation is a natural byproduct of the arising choice preferences of the decision maker. When including all trials in the analysis, target options remained more likely to be chosen than nontarget options (OR = 1.17, 95% CI = [1.05, 1.30], $z = 2.83$, $p = .005$). However, when analyzing only self-determined choices, the target option was chosen in only 37.56% of the trials (OR = 0.45, 95% CI = [0.36, 0.57], $z = -6.68$, $p < .001$). This reversal of the effect is a first indication for possible selection effects (a more detailed analysis is described below).

Comparing self-determined to interrupted choices, the results showed that the link between last fixation and the subsequent choice is stronger for self-determined than for interrupted trials (OR = 0.46, 95% CI = [0.33, 0.66], $z = -4.24$, $p < .001$, Table 4C). These findings indicate that even though the link between the last fixation and the subsequent choice was systematically stronger in an uninterrupted preference formation process (top-down), we also observed an effect when the process was exogenously interrupted (bottom-up).

[21] $100 / OR_{self\text{-}determined} \times OR_{interrupted} = 100 / 9.45 \times 3.44 = 36.40$

Table 4

Choice of right option predicted by last fixation for interrupted (A) and self-determined trials (B) and both trials combined (C).

	(A) Self-determined OR (right option)		(B) Interrupted OR (right option)		(C) Pooled OR (right option)	
Last fixation right	9.45^{***}	[6.48, 13.78]	3.44^{***}	[2.76, 4.29]	5.46^{***}	[4.41, 6.77]
Relative time advantage right	4.85^{***}	[3.45, 6.81]	2.33^{***}	[1.90, 2.86]	3.48^{***}	[2.85, 4.25]
Confidence	0.96	[0.88, 1.04]	0.95^{*}	[0.90, 0.99]	0.95^{*}	[0.91, 1.00]
Trial number	1.00^{*}	[0.99, 1.00]	1.00	[0.999, 1.00]	1.00	[1.00, 1.00]
Interrupted trial	-		-		0.76^{***}	[0.65, 0.89]
Last fixation right × interrupted trial	-		-		0.46^{***}	[0.33, 0.66]
Constant	0.62	[0.34, 1.14]	0.58^{**}	[0.42, 0.81]	0.93^{+}	[0.85, 1.01]
Observations	2540		2912		5452	

Note. Odds Ratios; 95% confidence intervals in brackets. For C all variables were centered, * $p < .05$, ** $p < .01$, *** $p < .001$.

Comparing attention-choice relationship across domains. To further understand the decision process and the role of attention within it, we tested for potential differences between other-regarding and moral decisions. We replicated the well-established correlation between attention and choices, in that the alternative attended to last was chosen in 71.68% of other-regarding (OR = 7.73, 95% CI = [4.88, 12.24], $z = 8.71$, $p < .001$) and 73.89% of moral choices (OR = 12.58, 95% CI = [8.20, 19.28], $z = 11.60$, $p < .001$). In contrast, in the interrupted sample, the lastly attended alternative was chosen in 59.49% of trials (OR = 2.85, 95% CI = [2.17, 3.74], $z = 7.53$, $p < .001$). For moral choices, participants chose the last fixated alternative in 64.57% of trials (OR = 4.03, 95% CI = [3.06, 5.31], $z = 9.93$, $p < .001$).

Comparing trials with self-determined last fixations to trials with experimentally manipulated last fixations, the results showed, in both domains, that the link between the last fixation and the subsequent choice is weaker for interrupted in contrast to self-determined trials (other-regarding: OR = 0.50, 95% CI = [0.32, 0.78], $z = -3.05$, $p = .002$; moral choices: OR = 0.41, 95% CI = [0.27, 0.64], $z = -3.98$, $p < .001$). Figure 13 shows a comparison of the bottom-up link between attention and subsequent choices (interrupted) and the top-down influence (self-determined) for other-regarding and moral trials. To test the context dependency directly, we compared other-regarding to moral trials. The results indicated that the top-down influence of the last fixation on choice behavior was stronger for moral than for other-regarding trials (OR = 1.61, 95% CI = [1.07, 2.42], $z = 2.29$, $p = .022$). However, for the bottom-up effect of attention on choices, there is a reduced difference between other-regarding and moral trials (OR = 1.28, 95% CI = [0.94, 1.74], $z = 1.54$, $p = .123$; for more details, see the supplement).

To explore the context dependency of the bottom-up effect of last fixation on choices in more detail, we analyzed the overall sample. When including only other-regarding trials in the analysis, the bottom-up effect of last fixation on choices did not hold (OR = 1.08, 95% CI = [0.93, 1.26], $z = 1.06$, $p = .289$). In contrast, for moral trials, the link between the pre-determined target option and subsequent choices prevailed (OR = 1.26, 95% CI = [1.09, 1.45], $z = 3.21$, $p = .001$; see Figure 13 *Overall*). These results indicate that, for other-regarding trials, the bottom-up effect of the last fixation on choices might be the result of a selection bias. Overall, when including all trials, target options were still 4% more likely to be chosen than nontarget options but this difference is only driven by moral choices.

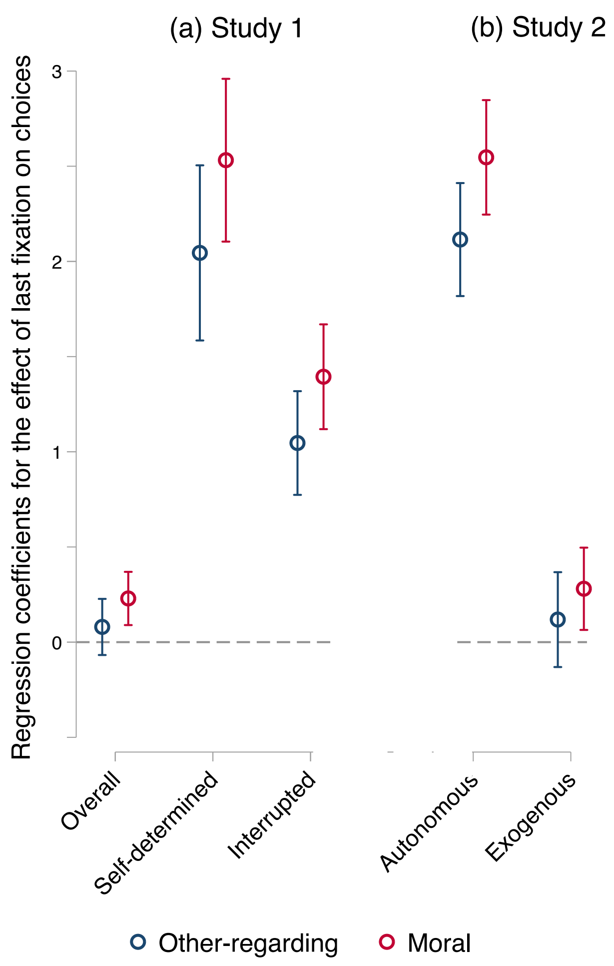

Figure 13. Regression coefficients for the effect of last fixation on choice behavior for (a) Study 1 and (b) Study 2. For Study 1, the effect is displayed for all trials, self-determined trials, and interrupted trials (N = 116). For Study 2, the effect is displayed for the autonomous (n = 50) and exogenous groups (n = 50). At coefficient = 0 (dashed line), the last fixated and non-fixated option are equally likely to be chosen. Error bars indicate 95% confidence intervals.

Note. The *Overall* estimation displays the likelihood of choosing the right vs. left option predicted by the location of the target (right / left), whereas in all other estimations choices are predicted using last fixation (right / left) instead of target location.

Considering selection effects. Choosing the pre-determined target option varied strongly between interrupted and self-determined trials. Whereas the randomly allocated target alternative was more likely to be chosen in interrupted trials (OR = 3.44, 95% CI = [2.76, 4.29], z = 10.96, p < .001), the effect reversed in self-determined trials (OR = 0.45, 95% CI = [0.36, 0.57], z = -6.68, p < .001). This systematic reversion of the effect indicates that the trials in which the decision prompt criteria were not fulfilled were not a random selection. Target choices were not influenced by confidence (OR = 1.02, 95% CI = [0.99, 1.06], z = 1.28, p = .202) and perceived importance of the topic (OR = 1.01, 95% CI = [0.98, 1.05], z = 0.86, p = .387).

In order to better understand the underlying processes and the potential selection bias present in our data, we analyzed the factors that influence the likelihood to fulfill all three decision prompt criteria. Particularly, we identified three factors increasing the likelihood of a self-determined trial. Self-determined trials were more likely if the nontarget option was selected (OR = 0.25, 95% CI = [0.21, 0.30], z = -14.11, p < .001) and participants were confident in their decision (OR = 1.44, 95% CI = [1.35, 1.55], z = 10.27, p < .001) as well as the later the trial appeared in the course of the experiment (OR = 1.01, 95% CI = [1.00, 1.01], z = 4.45, p < .001). We also examined how a preference for the left or right alternative affected the likelihood of making a choice before the decision trigger was sent (self-determined trial). Due to the natural left bias in reading, trials were more likely to be self-determined if the alternative on the right was chosen (OR = 1.36, 95% CI = [1.14, 1.62], z = 3.47, p = .001). To further investigate potential selection effects, we analyzed which factors influenced the likelihood of a timeout to occur. Timeouts were more likely to occur when participants chose the nontarget option (OR = 0.43, 95% CI = [0.36, 0.52], z = -8.92, p < .001) and when they were less confident of their answer (OR = 0.90, 95% CI = [0.86, 0.95], z = -4.31, p < .001). These results indicate that using the gaze-contingent paradigm led to systematic differences between target and nontarget choices.

Study 2

While informative, the revealed selection effects do not allow to draw conclusive inferences from the findings presented in Study 1 (for a discussion of the same problem, see also Newell & Le Pelley, 2018). Hence, pre-registered Study 2 utilized a decision paradigm that allowed to fully control information intake to test for the influence of attention on choice. As in Study 1, we hypothesized that last fixations would be predictive for choice behavior even when information presentation was exogenously determined by the information search of another person (H1). We assumed that this effect would be stronger if information search was autonomous (H2). Following up on the findings of Study 1, we also hypothesized that the relationship between attention and choices would be stronger for moral than for other-regarding choices (H3).

Method

Participants. One hundred five participants (mean age = 22.82 years, 68% female) from the Max Planck Decision*L*ab subject pool (students of the University of Bonn) were recruited via Orsee (Greiner, 2015). The experiment, which took approximately 30 minutes to complete, was the first in a two-study experimental battery lasting a total of approximately 60 minutes (the second unrelated study was designed by a different experimenter). Participants received an average payoff of 11.50 €. All participants signed a consent form for taking part in experimental studies and were debriefed after the experiment. Using data from the first study, we conducted an a priori simulation based power analysis. Aiming at a power of .8 revealed a target sample size of 66 complete data sets. Assuming that the effect of the last fixation on subsequent choices would be overestimated in this power analysis due to the selection effects discussed above, we aimed to collect data from at least 100 participants. Following the procedure in Study 1, trials in which participants indicated that they had not been able to see both alternatives (2.64%) were excluded. Participants who correctly guessed the goal of the study (n = 5) were also excluded, resulting in a final sample of 100 participants.

Materials and Procedure. Following the same procedure as in Study 1, participants completed the fully incentivized SVO Ring Measure (Liebrand & McClintock, 1988) online at least 12 hours prior to participating in the experiment. Upon arriving at the laboratory all participants were presented with the same 90 statements as in Study 1 via headphones. After completing the experiment, participants were asked about their assumptions regarding the goal of the study. See bit.do/osf-Material for a complete list of items, original instructions, recordings and the experimental program.

Using a between-subjects design, participants were assigned to either the *autonomous* (n = 50) or the *exogenous* condition (n = 50). Participants of the *autonomous* condition were seated in front of a laptop (12.2" × 6.7" screen, color monitor with a native resolution of 1600 × 900). After reading the instructions, (all normal or corrected to normal vision) were calibrated to an EyeTribe eye-tracking device (30 Hz sampling rate, accuracy ~ 0.5°) and completed a 9-point calibration procedure on a grey background. During the experiment both alternatives appeared simultaneously on the screen after the audio recording was played. Two non-overlapping AOIs were defined with the same properties as in Study 1 containing the two alternatives. Participants were asked to make their choice within a given time frame ranging between 1 and 4 seconds for the first five trials and 1 and 3.5 seconds for all following trials. These are the mean decision times identified in a pre-test in which participants made the same choices without time constraint. By reducing the time frame after five trials, we adjust for learning effects. The time frame is set to reduce variance in the decision times and participants received feedback accordingly. During each trial, participants could inspect the information freely.

To test whether the link between last fixation and subsequent choices holds even when information search is exogenously determined, we adapted the paradigm used in Study 1. In the exogenous condition, alternatives were presented in a timely sequence based on viewing patterns of autonomous decision makers (see Figure 14). By presenting the information search of decision maker A to decision maker B, we hypothesized that their subsequent choices could be aligned. While individuals followed their natural gaze pattern in the autonomous choice condition, participants' information intake in the exogenous condition was determined by a matched presentation pattern. We sampled four versions of viewing patterns, two where the original decision maker chose option A and another two where the decision maker eventually chose option B (while option A was presented on the left or right side). It was randomly determined, which of the four versions participants completed. Note that this makes it equally likely that the last presented option would be on the left or the right option. By using gaze patterns of autonomous decision makers, we determined 1) the order in which alternatives were presented, 2) the presentation length, and 3) the frequency with which an alternative was presented. The set of presentation patterns was systematically constructed to reflect a decision process in which the last fixated alternative was selected in an autonomous choice. Fixation durations in autonomous choices determined the presentation length in the sequential presentation paradigm. When presenting information simultaneously, transitions from one alternative to the other are unobstructed. However, transitions are slightly delayed when information is presented sequentially, as attention can only be oriented towards the alternative after it is displayed. To account for such differences in transition time due to the change in presentation format, we conducted a pre-test. In doing so, we measured the delay in transitions that individuals experienced when alternatives were presented sequentially rather than simultaneously (M = 344 ms). This time delay was added to each presentation of individual alternatives to ensure that fixation durations were as similar as possible in the two conditions.

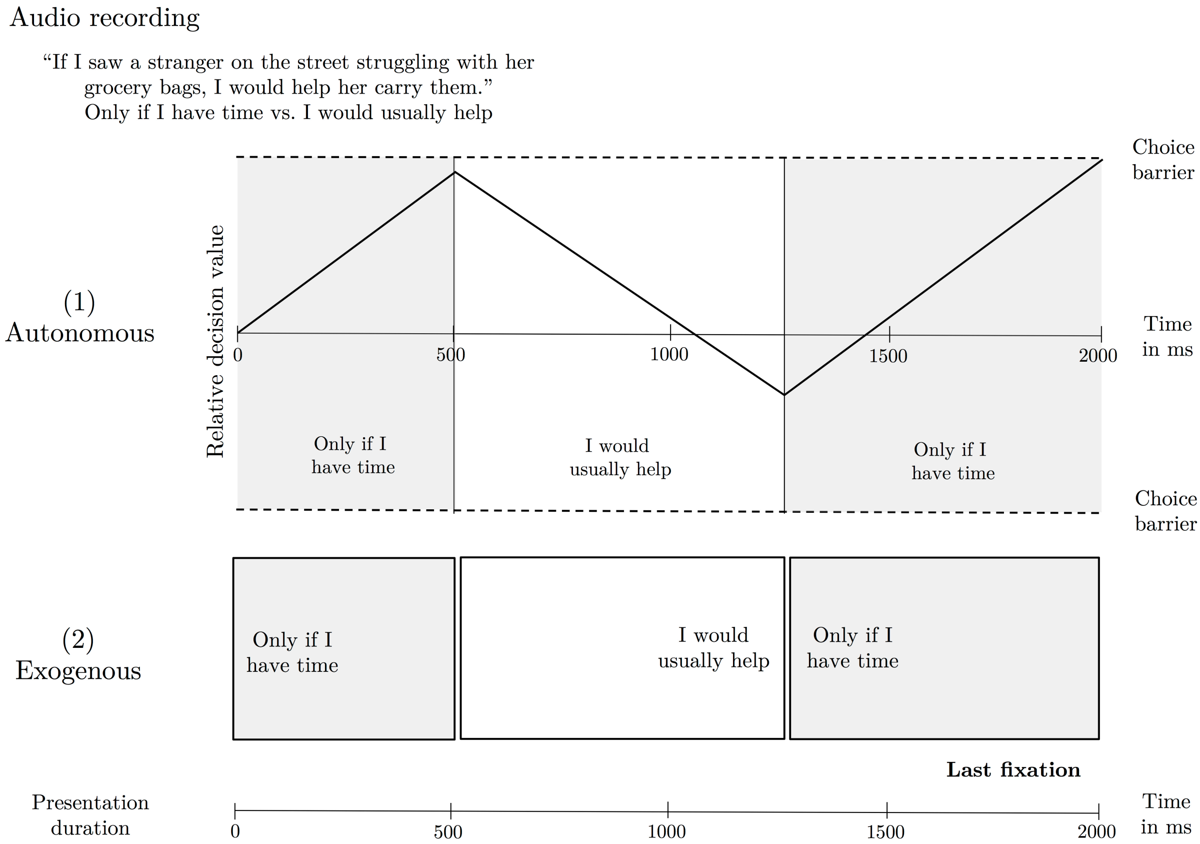

Figure 14. Autonomous group (1): Participants viewed the alternatives until they made their decision. The graph represents a stereotypical viewing pattern of an uninterrupted decision maker. The left alternative was fixated first for 500 ms, followed by the right alternative for 750 ms. Finally, the left alternative was then fixated again for 750 ms before making a choice. Exogenous group (2): The naturalistic gaze pattern in autonomous choices was exploited to define the sequential presentation of alternatives. Participants were prompted to choose after the alternatives were presented. For presentation purposes, the background color and font color of the stimuli were adapted for this figure.

Results

As in Study 1, and as defined in the study pre-registration, all of the following tests used a repeated measurement logistic regression predicting the final choice by the last fixation (left, right) and again controlled for relative time advantage, time effects (trial number), and participants' perceived confidence in their answer. In all regression analyses, we calculated robust standard errors. The raw data and pre-processing script can be found here bit.do/osf-Data; the complete analysis script can be found here: bit.do/osf-Analysis. All hypotheses and analyses have been pre-registered (bit.do/osf_Pre-Registration).

Magnitude of top-down and bottom-up mechanisms. Replicating the results found in Study 1, the analysis shows a strong correlational link between attention and autonomous other-regarding and moral choices. Specifically, 76.87% of all last fixated alternatives were subsequently chosen (Table 5A). To determine whether and to what extent this link is driven by the influence of attention on the subsequent choice, we analyzed the exogenous group in which information intake was determined by another person's viewing pattern. The results lend support to H1, showing that even completely exogenously determined last fixations were predictive of subsequent choices (Table 5B). Hence, the actual influence of attention on choices is only 11.32%[22], in contrast to 36.40% in the overestimated effect for interrupted trials in Study 1. The remaining variance can most likely be attributed to attention being the natural byproduct of the top-down decision making process. As participants in the exogenous condition chose the target option 51.19% of the trials, this equates to a 1.19% change in choices overall. Comparing the coefficients to Study 1 indicates how the bottom-up effect of last fixation on choices was overestimated within the gaze-contingent paradigm (see Figure 13).

Testing the assumption of H2, we analyzed the magnitude of top-down to bottom-up mechanisms for the link between attention and choices. To do so, autonomous last fixations were compared to exogenous last fixations in order to disentangle top-down from bottom-up processes. In line with H2 and the results of Study 1, the link between last fixation and subsequent choices is weaker for the exogenous as compared to the autonomous group (OR =

[22] $100 / 10.87 \times 1.23 = 11.32$

0.07, 95% CI = [0.06, 0.09], z = -20.67, p < .001, Table 5C).

Table 5

Choice of right option predicted by last fixation for the autonomous (A), exogenous group (B), and both groups combined (C).

	(A) Autonomous OR (right option)		(B) Exogenous OR (right option)		(C) Pooled OR (right option)	
Last fixation right	10.87^{***}	[8.78, 13.45]	1.23^{*}	[1.04, 1.44]	3.15^{***}	[2.77, 3.59]
Relative time advantage right	4.26^{***}	[3.53, 5.14]	0.84^{**}	[0.75, 0.94]	1.42^{***}	[1.29, 1.56]
Confidence	0.96	[0.90, 1.03]	1.00	[0.94, 1.05]	0.98	[0.94, 1.02]
Trial number	1.00	[1.00, 1.00]	1.00	[1.00, 1.00]	1.00	[1.00, 1.00]
Exogenous group	-		-		1.29^{***}	[1.11, 1.49]
Last fixation right × exogenous group	-		-		0.07^{***}	[0.06, 0.09]
Constant	0.34^{***}	[0.21, 0.54]	0.85	[0.59,1.23]	0.88^{***}	[0.82, 0.95]
Observations	2754		2932		5686	

Note. Odds Ratios; 95% confidence intervals in brackets. For C all variables are centered, * p < .05, ** p < .01, *** p < .001.

Comparing attention-choice relationship across domains. Disentangling the overall effect of last fixation on choices, the findings indicate that the last attended alternative was chosen in 78.71% of autonomous moral choices (OR = 12.77, 95% CI = [9.45, 17.25], z = 16.60, p < .001) and 75.02% of autonomous other-regarding choices (OR = 8.46, 95% CI = [6.27, 11.41], z = 13.97, p < .001). Testing the exogenous group, we found, as predicted, a substantially reduced influence of attention on choice for moral choices with a likelihood of choosing the target option of 52.79% (OR = 1.32, 95% CI = [1.07, 1.64], $z = 2.55$, $p = .011$). Testing the same relationship for other-regarding decisions, we found no support for the causal link, as participants chose the target option in 49.59% of the trials (OR = 1.13, 95% CI = [0.88, 1.45], $z = 0.95$, $p = .342$). When analyzing whether the attention-choice relationship is more pronounced for moral as opposed to other-regarding choices (H3), results replicate the pattern in Study 1, in that the top-down influence of last fixation on choice behavior is stronger for moral choices than other-regarding choices ((OR = 1.48, 95% CI = [1.01, 2.17], $z = 1.99$, $p = .047$, see Figure 13). As expected, there is again no difference between other-regarding and moral choices for exogenously guided attention on choices (OR = 1.22, 95% CI = [0.91, 1.64], $z = 1.31$, $p = .190$).

Discussion

The current studies provide a systematic and critical test of the interplay of top-down and bottom-up processes between attention and choice preference. Additionally, we demonstrate how previous work systematically overestimated the influence of attention on choice using the gaze-contingent paradigm within simple, two-alternative decisions. For moral choices, though not for other-regarding ones, we present evidence for the influence of attention on choice. As expected, last fixations were more strongly linked to subsequent choices when they occurred as a byproduct of the preference formation process (top-down) than when experimentally manipulated (bottom-up).

Previous research supports the notion of a two-channel mechanism. On the one hand, personal preferences and motivations were identified as drivers of observable attentional mechanisms during the choice process (e.g., Fiedler et al., 2013). Our findings fit into this line of research by showing that last fixations were especially predictive of choices as part of the top-down preference formation. On the other hand, past studies repeatedly illustrated the influence of bottom-up features of the presentation, such as salience (Shen & Urminsky, 2013) and serial position on final choice outcomes (Mantonakis, Rodero, Lesschaeve, & Hastie, 2009). Hence, the presented evidence lends support to the ideas of the aDDM – in particular, its prediction that the last fixated option is more likely to be chosen. This notion of people's preferences being actively constructed during the decision making process was put forward as one explanation for the dynamic nature of our decisions (Simon & Spiller, 2016). An alternative explanation for the bottom-up link between attention and choices is the recency effect (Baddeley & Hitch, 1993). Since the alternatives are no longer visible at the time of the decision the likelihood of choosing the last fixated option could be driven by its availability in participants' memory.

In order to investigate the level of universality of this proposed attention-choice relationship, we tested for its context dependency. The respective results showed that the link between attention and choice was systematically stronger for moral than for other-regarding choices in both studies. There are several aspects that distinguish other-regarding from moral choices that may offer an explanation for these differences. First, other-regarding choices relate to issues that people encounter often in their everyday lives (e.g., helping someone carry grocery bags), whereas most of the moral issues relate to more abstract and novel situations (e.g., whether murder is sometimes justified). In novel situations, underlying preferences supposedly have not yet been formed. Attention, therefore, reflects the preference formation process more strongly. Second, it has been argued that, in moral choices, decision makers take the perspective of an "impartial spectator" when making a judgment (Smith, 1976). In contrast, decisions in other-regarding situations are made from a first-person account (Harsanyi, 1977).

From a methodological perspective, our results point to some shortcomings of the gaze-contingent paradigm. While, at first glance, it appeared to be an unobtrusive tool to manipulate last fixations within the decision making process, our analysis showed it is met with limitations. At the cost of extensive selection effects, the causal influence of attention was overestimated by 25.08% in moral choices. When critically tested in the sequential sampling paradigm, it was even eliminated in other-regarding decisions. One strength but also limitation of our sampling paradigm using natural viewing patterns is that they are not randomly matched to stimuli. On the one hand, this ensures that participants have a chance to read all the information available while still being under time pressure. But on the other hand, it reduces the level of randomization and might subsequently create stimuli dependency. We went to great length to maximize the suitability of the design under the constraints mentioned above, but encourage future replications of the results in particular with different items.

Conclusion

The evidence highlights the function of attention as a driver and byproduct of decision making. This work shows the context dependency of the observed links between attention and choice, in particular, and thus informs policies designed to support decision makers. Since many everyday decisions are based on complex and dynamic processes, they can potentially be influenced by guiding attention or systematic interruptions of the decision process. Taking a closer look at the underlying attentional mechanisms offered a novel perspective on the complex interplay between top-down and bottom-up processes as well as the limited influence that bottom-up processes have within moral and especially other-regarding decisions.

Author contributions

SF developed the study concept. Both authors contributed to the study design. Testing, data collection, data analysis and interpretation were performed by MG under the supervision of SF. MG drafted the manuscript, and SF provided critical revisions. Both authors approved the final version of the manuscript for submission.

Acknowledgments

We thank André Schmelzer, Felix Henninger, and Rima-Maria Rahal for helpful comments on previous drafts of this paper.

General Discussion

In the current dissertation, two questions were studied in more detail regarding decisions in social dilemmas: (1) To what extent do individual differences affect cognitive capacities and processes in social dilemmas? (2) How stable are decisions in these situations and does attention have the power to influence them? The present research addresses these questions by measuring eye movements in a range of social preference choices. Within Chapter I and II, the role of individual differences in cognitive capacities (i.e., memory) and information search is investigated in the context of simple money allocation tasks and strategic social dilemmas. Exploring the relation between attention and other-regarding decisions in more detail, Chapter III examines how stable social preference choices are and how exogenously manipulating the decision situation can affect choices.

The findings presented in Chapter I and II indicate that individual differences, in particular people's social preferences, are reflected in cognitive capacities and information search. Specifically, prosocial individuals were more likely to correctly recall their interaction partners' behavior in social dilemmas. This memory advantage is mediated by more extensive information search during encoding. Further, differences in information search are also observed in strategic settings, where own payoffs are dependent on other's choices. The results presented in Chapter III reveal that social preference choices can be affected by manipulating information presentation and decision time. These findings contribute to the debate on the causal relationship between attention and choices and estimate the respective magnitude of top-down and bottom-up processes linking attention to choices. While the top-down channel has a stronger influence on choices, some variance can also be explained through bottom-up effects. Additionally, the chapter critically discusses potential selection effects associated with paradigms.

In the following, methodological limitations that apply to all chapters are discussed and suggestions for future research are provided. Finally, implications of the findings reported in this dissertation are proposed.

Methodological limitations and future directions

In the following, some of the methodological limitations associated with the presented studies are discussed. First, using economic games to study behavior has received criticism due to the artificially constructed decision situation. While the highly simplified and controlled settings offer a number of advantages, they are limited by the decontextualized nature of the situation. Particularly psychologists argue that real-word interactions rarely have the same features as economic games. In real life, counterparts are usually not anonymous and consequences of actions are not presented in matrices displaying monetary payoffs, which questions the generalizability of behavior in economic games (e.g., Pruitt & Kimmel, 1977). At the same time, behavior in economic games was found to be closely related to the real world (Gintis, Bowles, Boyd, & Fehr, 2003) and their abstractness allows them to be used to study a wide range of phenomena in a standardized way (Osborne & Rubinstein, 1994). Nonetheless, future research should aim to study cognitive processes in situations that are more similar to situations people encounter in their everyday lives. For example, Dietze and Knowles (2016) took a first step in this direction by recording eye movements with a mobile eye-tracking device in naturalistic environments.

Second, the studies reported in this dissertation are conducted using student samples. Students usually differ in their demographic characteristics from the general population, especially regarding age, socio-economic background and education, which limits the generalization of research findings (Hanel & Vione, 2016). The samples used in the present studies have previously been described as WEIRD (Western, educated, industrialized, rich and democratic), highlighting the cultural characteristics that distinguish these individuals from the general population. These differences were argued to be problematic in the generalization of psychological findings from WEIRD individuals to the general population (Henrich, Heine, & Norenzayan, 2010). In a similar vein, students were found to systematically behave differently in economic games than non-students (Belot, Duch, & Miller, 2015). Regarding basic research phenomena, however, a number of factors were not affected by participants' characteristics. For example, cognitive processes underlying social relationships revealed similar patterns across distinct populations (Fiske, 1993). Further, self-selected student participants were found to be an appropriate subject pool for the study of social behavior and conclusions about the representative population (Exadaktylos, Espin, & Branas-Garza, 2013). To systematically estimate whether the present findings generalize to the general population, future research should aim to use non-student and culturally more diverse samples when studying decision processes in social dilemmas.

Third, the studies reported in this dissertation include online as well as laboratory studies. Both types of studies bring advantages as well as limitations with them. Conducting online studies have become more popular with the rise of digitalization. They constitute a very cost and time efficient way of collecting data (for an extensive overview see Reips, 2002). Less time is required as the number of participants is not restricted by space in the laboratory, participants do not have to be paid a show-up fee and no personnel is required. This efficiency allows for an increased sample size as compared to laboratory studies, which makes findings more robust. The advantages of efficiency and robustness in online studies come at the cost of control. In online studies, researchers do not have any control over the setting in which participants complete their study and the potential distractions they are confronted with (Reips, 2002). Here, laboratory studies have the advantage of offering a highly controlled research environment (Falk & Heckman, 2009). Using standardized procedures during data collection, it can be ensured that participants complete studies under very similar conditions. Laboratory studies, however, put participants in a very artificial decision environment that is likely to differ from the real world. Thus, high internal validity of laboratory studies comes at the cost of external validity. Future research should aim to use a combination of both types of studies in order to have a robust estimation of the effect under consideration and identify potential boundaries. Design choices should be carefully adapted to the setting the experiment is conducted in. For instance, in Chapter I of this dissertation, both types of studies were combined in order to robustly estimate the effect of social preferences on memory performance in social interactions.

Implications

The findings presented in this dissertation offer a number of relevant theoretical and practical implications. In the following, some of these implications are discussed with regard to their merit.

Several of the here presented, but also previous studies have examined the influence of individual differences on information processes. These findings have relevant theoretical implications. For instance, the bounded rationality framework proposed that decision processes are limited by individual information processing. The results reported here, support this notion by showing that attention allocation is driven by individual preferences and corresponds to the motives each individual pursues. This is consistent with evidence showing that players selectively attended to information that is relevant to them (Hristova & Grinberg, 2005), in particular their own payoffs (Devetag et al., 2016). Further, the current findings suggest that models formalizing strategic thinking (e.g., level-k) could predict strategic considerations more accurately by taking individual social preferences into account. Similarly, simulations modeling behavior in repeated interactions could be improved by taking into account that reciprocal strategies are supposedly more feasible for prosocial than for proself individuals.

Considering the number of social interactions we experience in everyday life, findings on the link between social preferences and cognitive capacities have also important practical implications. Presumably, prosocial individuals are better equipped to engage in cooperative social interactions, as they form more accurate expectations of their partner's future behavior. For example, when working on a joint project with a coworker, paying attention to the consequences of working together not only for oneself but also for the coworker can facilitate recalling that coworker's behavior later. Importantly, remembering previous behavior can sustain cooperative actions between prosocial coworkers. Engaging in bilateral cooperation across long periods of time is beneficial not only to coworkers, but also to the company for which they work. Given the crucial economic and societal benefits of engaging in cooperative social interactions, it is important to note that a lack of memory is a possible reason for systematic deviations from cooperation.

Further, this work shows the context dependency of the observed links between attention and choice, in particular, and thus informs policies designed to support decision makers. Since many everyday decisions are based on complex and dynamic processes, they can potentially be influenced by guiding attention or systematic interruptions of the decision process. Taking a closer look at the underlying attentional mechanisms offered a novel perspective on the complex interplay between top-down and bottom-up processes as well as the limited influence that bottom-up processes have within moral and especially other-regarding decisions.

Conclusion

Since the beginning of the cognitive revolution, researchers' understanding of the cognitive processes underlying choices has made considerable progress. Here, we enhance existing knowledge by particularly studying decision processes in social dilemmas. In sum, the results of this dissertation indicate that individual's social preferences predict systematic differences in cognitive capacities (i.e., memory performance) and information search processes within social interactions. Within these processes, attention patterns reflect weighting processes associated with individual social preferences and the final choice. Uncovering some of the strategic contemplations people are facing in social dilemmas, temporal dynamics show that attention allocation unfolds differently for cooperative and defective choices. Studying the link between attention and choice behavior in more detail, the results reveal that while other-regarding choices can be influenced by exogenously guiding attention, they are mostly driven by a top-down influence of individual preferences on choices. The findings of this dissertation contribute to the research on social dilemmas as they shed light on the impact of social preferences on cognitive capacities and processes and develop a preliminary understanding of the underlying drivers of other-regarding decisions.

References

Appelt, K. C., Milch, K. F., Handgraaf, M. J. J., & Weber, E. U. (2011). The Decision Making Individual Differences Inventory and guidelines for the study of individual differences in judgment and decision-making research. *Judgment and Decision Making, 6*(3), 252-262.

Armel, K. C., Beaumel, A., & Rangel, A. (2008). Biasing simple choices by manipulating relative visual attention. *Judgment and Decision Making, 3*(5), 396-403.

Ashby, N. J., Johnson, J. G., Krajbich, I., & Wedel, M. (2016). Applications and Innovations of Eye-movement Research in Judgment and Decision Making. *Journal of Behavioral Decision Making, 29*(2-3), 96-102. doi: 10.1002/bdm.1956

Ashby, N. J., Walasek, L., & Glöckner, A. (2015). The effect of consumer ratings and attentional allocation on product valuations. *Judgment and Decision Making, 10*(2), 172-184.

Ashton, M. C., & Lee, K. (2009). The HEXACO-60: a short measure of the major dimensions of personality. *Journal of personality assessment, 91*(4), 340-345. doi: 10.1080/00223890902935878

Atalay, A. S., Bodur, H. O., & Rasolofoarison, D. (2012). Shining in the Center: Central Gaze Cascade Effect on Product Choice. *Journal of Consumer Research, 39*(4), 848-866. doi: 10.1086/665984

Atance, C. M., & O'Neill, D. K. (2001). Episodic future thinking. *Trends in cognitive sciences, 5*(12), 533-539.

Axelrod, R., & Hamilton, W. D. (1981). The evolution of cooperation. *Science, 211*(4489), 1390-1396.

Baddeley, A. D., & Hitch, G. (1993). The recency effect: Implicit learning with explicit retrieval? *Memory & Cognition, 21*(2), 146-155.

Bakker, M., van Dijk, A., & Wicherts, J. M. (2012). The Rules of the Game Called Psychological Science. *Perspectives on psychological science, 7*(6), 543-554. doi: 10.1177/1745691612459060

Balliet, D., Parks, C., & Joireman, J. (2009). Social Value Orientation and Cooperation in Social Dilemmas: A Meta-Analysis. *Group Processes & Intergroup Relations, 12*(4), 533-547. doi: 10.1177/1368430209105040

Barclay, P., & Lalumière, M. L. (2006). Do people differentially remember cheaters. *Human Nature, 17*(1), 98-113.

Bargh, J. A., & Chartrand, T. L. (1999). The unbearable automaticity of being. *American Psychologist, 54*(7), 462-479.

Bell, R., & Buchner, A. (2010). Justice sensitivity and source memory for cheaters. *Journal of Research in Personality, 44*(6), 677-683. doi: 10.1016/j.jrp.2010.08.011

Bell, R., & Buchner, A. (2011). Source memory for faces is determined by their emotional evaluation. *Emotion, 11*(2), 249-261. doi: 10.1037/a0022597

Bell, R., Koranyi, N., Buchner, A., & Rothermund, K. (2017). The implicit cognition of reciprocal exchange: automatic retrieval of positive and negative experiences with partners in a prisoner's dilemma game. *Cognition and emotion*, 1-18. doi: 10.1080/02699931.2016.1147423

Belot, M., Duch, R., & Miller, L. (2015). A comprehensive comparison of students and non-students in classic experimental games. *Journal of Economic behavior & Organization, 113*, 26-33. doi: 10.1016/j.jebo.2015.02.007

Berkowitsch, N. A., Scheibehenne, B., & Rieskamp, J. (2014). Rigorously testing multialternative decision field theory against random utility models. . *Journal of Experimental Psychology: General, 143*(3), 1331-1348. doi: 10.1037/a0035159.supp

Bettman, J. R., Johnson, E. J., Luce, M. F., & Payne, J. W. (1993). Correlation, conflict, and choice. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19*(4), 931-951.

Bird, G. D., Lauwereyns, J., & Crawford, M. T. (2012). The role of eye movements in decision making and the prospect of exposure effects. *Vision research, 60*, 16-21. doi: 10.1016/j.visres.2012.02.014

Bloom, L. C., & Mudd, S. A. (1991). Depth of processing approach to face recognition: a test of two theories. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17*(3), 556-565.

Bogaert, S., Boone, C., & Declerck, C. (2008). Social value orientation and cooperation in social dilemmas: a review and conceptual model. *Br J Soc Psychol, 47*(Pt 3), 453-480. doi: 10.1348/014466607X244970

Böhringer, C., & Vogt, C. (2003). Economic and environmental impacts of the Kyoto Protocol. *Canadian Journal of Economics, 36*(2), 475-496.

Bolton, G. E., & Ockenfels, A. (2000). ERC: A theory of equity, reciprocity, and competition. *American Economic Review, 90*(1), 166-193.

Bornstein, B. H., Deffenbacher, K. A., Penrod, S. D., & McGorty, E. K. (2012). Effects of exposure time and cognitive operations on facial identification accuracy: a meta-analysis of two variables associated with initial memory strength. *Psychology, Crime & Law, 18*(5), 473-490. doi: 10.1080/1068316x.2010.508458

Bouwmeester, S., Verkoeijen, P. P., Aczel, B., Barbosa, F., Bègue, L., Brañas-Garza, P., . . . Herrero, A. (2017). Registered Replication Report: Rand, Greene, and Nowak (2012). *Perspectives on psychological science, 12*(3), 527-542.

Brown, J. (1958). Some tests of the decay theory of immediate memory. *Q J Exp Psychol (Hove), 10*(1), 12-21.

Buchner, A., Bell, R., Mehl, B., & Musch, J. (2009). No enhanced recognition memory, but better source memory for faces of cheaters. *Evolution and Human Behavior, 30*(3), 212-224. doi: 10.1016/j.evolhumbehav.2009.01.004

Busemeyer, J. R., & Townsend, J. T. (1993). Decision field theory: a dynamic-cognitive approach to decision making in an uncertain environment. *Psychological review, 100*(3), 432-459.

Buss, D. M. (1989). Sex differences in human mate preferences: Evolutionary hypotheses tested in 37 cultures. *Behavioral and brain sciences, 12*(1), 1-14.

Camac, C. (1992). Information preferences in a two-person social dilemma. In W. B. G. Liebrand, D. M. Messick & H. A. M. Wilke (Eds.), *Social dilemmas: Theoretical issues and research findings* (pp. 147-161). Elmsford, NY: Pergamon Press.

Camerer, C. F. (2003). Strategizing in the brain. *Science, 300*(5626), 1673-1675.

Camerer, C. F., Johnson, E. J., Rymon, T., & Sen, S. (1993). Cognition and framing in sequential bargaining for gains and losses. *Frontiers of Game Theory, 104*, 27-47.

Carlsson, F., Johansson-Stenman, O., & Nam, P. K. (2014). Social preferences are stable over long periods of time. *Journal of Public Economics, 117*, 104-114. doi: 10.1016/j.jpubeco.2014.05.009

Chen, C. T., Huang, C. Y., & Wang, J. T. Y. (2009). A window of cognition: Eyetracking the reasoning process in spatial beauty contest games. *National Taiwan University: Working paper*.

Chiappe, D., Brown, A., & Dow, B. (2004). Cheaters are looked at longer and remembered better than cooperators in social exchange situations. *Evolutionary Psychology, 2*(1), 108-120.

Chun, M. M., & Turk-Browne, N. B. (2007). Interactions between attention and memory. *Curr Opin Neurobiol, 17*(2), 177-184. doi: 10.1016/j.conb.2007.03.005

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2 ed.): Lawrence Erlbaum Associates.

Collaboration, O. S. (2012). An open, large-scale, collaborative effort to estimate the reproducibility of psychological science. *Perspectives on psychological science, 7*(6), 657-660. doi: 10.1177/1745691612462588

Collaboration, O. S. (2015). Estimating the reproducibility of psychological science. *Science, 349*(6251), aac4716. doi: 10.1126/

Conchar, M. P., Zinkhan, G. M., Peters, C., & Olavarrieta, S. (2004). An integrated framework for the conceptualization of consumers' perceived-risk processing. *Journal of the Academy of Marketing Science, 32*(4), 418-436. doi: 10.1177/0092070304267551

Cosmides, L., & Tooby, J. (1989). Evolutionary psychology and the generation of culture, part II: Case study: A computational theory of social exchange. *Ethology and Sociobiology, 10*(1), 51-97.

Costa-Gomes, M., Crawford, V. P., & Broseta, B. (2001). Cognition and behavior in normal-form games: An experimental study. *Econometrica, 69*(5), 1193-1235.

Cox, S. J., Slockin, T. J., & Steele, J. (1999). Group Size, Memory, and Interaction Rate in the Evolution of Cooperation *Current Anthropology, 40*(3), 369-376.

Davis, M. H. (1980). A multidimensional approach to individual differences in empathy. *JSAS Catalog of Selected Documents in Psychology, 10*(85).

Dawes, R. M., & Thaler, R. H. (1988). Anomalies: cooperation. *Journal of economic perspectives, 2*(3), 187-197.

De Cremer, D., Tyler, T. R., & Ouden, N. d. (2005). Managing cooperation via procedural fairness: The mediating influence of self-other merging. *Journal of Economic Psychology, 26*(3), 393-406. doi: 10.1016/j.joep.2004.12.004

De Cremer, D., & Van Lange, P. A. M. (2001). Why prosocials exhibit greater cooperation than proselfs: the roles of social responsibility and reciprocity. *European Journal of Personality, 15*(S1), S5-S18. doi: 10.1002/per.418

De Dreu, C. K., Nijstad, B. A., & van Knippenberg, D. (2008). Motivated information processing in group judgment and decision making. *Personality and social psychology review, 12*(1), 22-49. doi: 10.1177/1088868307304092

Declerck, C. H., & Bogaert, S. (2008). Social value orientation: related to empathy and the ability to read the mind in the eyes. *The Journal of social psychology, 148*(6), 711-726. doi: 10.3200/SOCP.148.6.711-726

Dehue, F. M., McClintock, C. G., & Liebrand, W. B. (1993). Social value related response latencies: Unobtrusive evidence for individual differences in information processing. *European Journal of Social Psychology, 23*(3), 273-193.

Devetag, G., Di Guida, S., & Polonio, L. (2016). An eye-tracking study of feature-based choice in one-shot games. *Experimental Economics, 19*(1), 177-201. doi: 10.1007/s10683-015-9432-5

Dietze, P., & Knowles, E. D. (2016). Social Class and the Motivational Relevance of Other Human Beings: Evidence From Visual Attention. *Psychological Science, 27*(11), 1517-1527. doi: 10.1177/0956797616667721

Donaldson, S. I., & Grant-Vallone, E. J. (2002). Understanding self-report bias in organizational behavior research. *Journal of business and Psychology, 17*(2), 245-260.

Duchowski, A. T. (2017). *Eye tracking methodology: Theory and practice* (Vol. 2). London, UK: Springer.

Earp, B. D., & Trafimow, D. (2015). Replication, falsification, and the crisis of confidence in social psychology. *Frontiers in psychology, 6*, 1-11. doi: 10.3389/fpsyg.2015.00621

Ebner, N. C., & Johnson, M. K. (2010). Age-Group Differences in Interference from Young and Older Emotional Faces. *Cognition and emotion, 24*(7), 1095-1116. doi: 10.1080/02699930903128395

Emonds, G., Declerck, C. H., Boone, C., Vandervliet, E. J. M., & Parizel, P. M. (2011). Comparing the neural basis of decision making in social dilemmas of people with different social value orientations, a fMRI study. *Journal of Neuroscience, Psychology, and Economics, 4*(1), 11-24. doi: 10.1037/a0020151

Evans, J. S. (2008). Dual-processing accounts of reasoning, judgment, and social cognition. *Annu Rev Psychol, 59*, 255-278. doi: 10.1146/annurev.psych.59.103006.093629

Everett, J. A. C., & Earp, B. D. (2015). A tragedy of the (academic) commons: interpreting the replication crisis in psychology as a social dilemma for early-career researchers. *Frontiers in psychology, 6*, 1-4. doi: 10.3389/fpsyg.2015.01152

Exadaktylos, F., Espin, A. M., & Branas-Garza, P. (2013). Experimental subjects are not different. *Sci Rep, 3*(1213), 1-6. doi: 10.1038/srep01213

Falk, A., & Heckman, J. J. (2009). Lab experiments are a major source of knowledge in the social sciences. *Science, 326*(5952), 535-538.

Fehr, E., & Fischbacher, U. (2002). Why social preferences matter - The impact of non-selfish motives on competition. *The Economic Journal, 112*(478), C1-C33.

Fehr, E., & Schmidt, K. M. (1999). A theory of fairness, competition, and cooperation. *The Quarterly Journal of Economics, 114*(3), 817-868.

Feyer, R., Leopold-Wildburger, U., & Pickl, S. (2007). The influence of social values in cooperation. In K. J & S. Nickel (Eds.), *Operations research proceedings 2007* (pp. 205-210). Berlin: Springer.

Fiedler, S., & Glöckner, A. (2012). The dynamics of decision making in risky choice: an eye-tracking analysis. *Frontiers in psychology, 3*(335), 1-18. doi: 10.3389/fpsyg.2012.00335

Fiedler, S., Glöckner, A., Nicklisch, A., & Dickert, S. (2013). Social Value Orientation and information search in social dilemmas: An eye-tracking analysis. *Organizational Behavior and Human Decision Processes, 120*(2), 272-284. doi: 10.1016/j.obhdp.2012.07.002

Fischbacher, U., Gächter, S., & Fehr, E. (2001). Are people conditionally cooperative? Evidence from a public goods experiment. *Economics letters, 71*(3), 397-404. doi: 10.3929/ethz-a-004372944

Fiske, A. P. (1993). Social errors in four cultures: Evidence about universal forms of social relations. *Journal of Cross-Cultural Psychology, 24*(4), 463-494.

Frankenhuis, W., & Nettle, D. (in press). *Perspectives on psychological science*.

Gerbasi, M. E., & Prentice, D. A. (2013). The Self- and Other-Interest Inventory. *J Pers Soc Psychol, 105*(3), 495-514. doi: 10.1037/a0033483

Germine, L., Nakayama, K., Duchaine, B. C., Chabris, C. F., Chatterjee, G., & Wilmer, J. B. (2012). Is the Web as good as the lab? Comparable performance from Web and lab in cognitive/perceptual experiments. *Psychonomic Bulletin & Review, 19*(5), 847-857.

Gigerenzer, G., & Selten, R. (2002). *Bounded rationality: The adaptive toolbox*: MIT press.

Gintis, H., Bowles, S., Boyd, R., & Fehr, E. (2003). Explaining altruistic behavior in humans. *Evolution and Human Behavior, 24*(3), 153-172. doi: 10.1016/s1090-5138(02)00157-5

Glaholt, M. G., & Reingold, E. M. (2009). Stimulus exposure and gaze bias: a further test of the gaze cascade model. *Atten Percept Psychophys, 71*(3), 445-450. doi: 10.3758/APP.71.3.445

Glöckner, A., & Betsch, T. (2008). Modeling option and strategy choices with connectionist networks: Towards an integrative model of automatic and deliberate decision making. *Judgment and Decision Making, 3*, 215-228.

Glöckner, A., & Herbold, A. (2011). An eye-tracking study on information processing in risky decisions: Evidence for compensatory strategies based on automatic processes. *Journal of Behavioral Decision Making, 24*(1), 71-98. doi: 10.1002/bdm.684

Glöckner, A., & Hilbig, B. E. (2012). Risk is relative: Risk aversion yields cooperation rather than defection in cooperation-friendly environments. *Psychonomic Bulletin & Review, 19*(3), 546-553. doi: 10.3758/s13423-012-0224-z

Glöckner, A., Hilbig, B. E., & Jekel, M. (2014). What is adaptive about adaptive decision making? A parallel constraint satisfaction account. *Cognition, 133*(3), 641-666. doi: 10.1016/j.cognition.2014.08.017

Glöckner, A., & Hodges, S. D. (2011). Parallel constraint satisfaction in memory-based decisions. *Experimental Psychology, 58*(3), 180-195. doi: 10.1027/1618-3169/a000084

Goehring, D. J., & Kahan, J. P. (1976). The uniform n-person prisoner's dilemma game construction and test of an index of cooperation. *Journal of Conflict Resolution, 20*(1), 111-128.

González, R. J. (2017). Hacking the citizenry?: Personality profiling,'big data'and the election of Donald Trump. *Anthropology Today, 33*(3), 9-12.

Greiner, B. (2015). Subject pool recruitment procedures: organizing experiments with ORSEE. *Journal of the Economic Science Association, 1*(1), 114-125. doi: 10.1007/s40881-015-0004-4

Güth, W., Schmittberger, R., & Schwarze, B. (1982). An experimental analysis of ultimatum bargaining. *Journal of Economic behavior & Organization, 3*(4), 367-388.

Halevy, N., & Chou, E. Y. (2014). How decisions happen: Focal points and blind spots in interdependent decision making. *Journal of personality and social psychology, 106*(3), 398-417.

Haley, K. J., & Fessler, D. M. T. (2005). Nobody's watching? Subtle cues affect generosity in an anonymous economic game. *Evolution and Human Behavior, 26*(3), 245-256. doi: 10.1016/j.evolhumbehav.2005.01.002

Hanel, P. H., & Vione, K. C. (2016). Do Student Samples Provide an Accurate Estimate of the General Public? *PLoS ONE, 11*(12), e0168354. doi: 10.1371/journal.pone.0168354

Harsanyi, J. C. (1977). Morality and the theory of rational behavior. *Social Research, 44*(4), 623-656.

Hayn-Leichsenring, G. U., Kloth, N., Schweinberger, S. R., & Redies, C. (2013). Adaptation effects to attractiveness of face photographs and art portraits are domain-specific. *Iperception, 4*(5), 303-316. doi: 10.1068/i0583

Henrich, J., Heine, S. J., & Norenzayan, A. (2010). The weirdest people in the world? *Behavioral and brain sciences, 33*(2-3), 61-135. doi: 10.1017/S0140525X0999152X

Hochman, G., Glöckner, A., Fiedler, S., & Ayal, S. (2016). “I can see it in your eyes”: Biased Processing and Increased Arousal in Dishonest Responses. *Journal of Behavioral Decision Making, 29*, 322-335.

Holmqvist, K., Nyström, M., Andersson, R., Dewhurst, R., Jarodzka, H., & Van de Weijer, J. (2011). *Eye tracking: A comprehensive guide to methods and measures.* Oxford: OUP.

Holt, C. A., & Laury, S. K. (2002). Risk Aversion and Incentive Effects. *American Economic Review, 92*(5), 1644-1655.

Hristova, E., & Grinberg, M. (2005). Information acquisition in the iterated prisoner’s dilemma game: An eye-tracking study. In B. G. Bara, L. Barsalou & M. Bucciarelli (Eds.), *Proceedings of the twenty-seventh annual conference of the Cognitive Science Society* (pp. 983-988). Hillsdale, NJ: Lawrence Erlbaum.

Huettig, F., Olivers, C. N., & Hartsuiker, R. J. (2011). Looking, language, and memory: bridging research from the visual world and visual search paradigms. *Acta psychologica, 137*(2), 138-150. doi: 10.1016/j.actpsy.2010.07.013

Iliev, R., Sachdeva, S., Bartels, D. M., Joseph, C., Suzuki, S., & Medin, D. L. (2009). Attending to Moral Values. *Psychology of learning and motivation, 50*, 169-192. doi: 10.1016/s0079-7421(08)00405-2

Itti, L., & Koch, C. (2001). Computational modelling of visual attention. *Nature reviews neuroscience, 2*(3), 194-203.

Jiang, T., Potters, J., & Funaki, Y. (2016). Eye-tracking Social Preferences. *Journal of Behavioral Decision Making, 29*(2-3), 157-168. doi: 10.1002/bdm.1899

John, L. K., Loewenstein, G., & Prelec, D. (2012). Measuring the prevalence of questionable research practices with incentives for truth telling. *Psychological Science, 23*(5), 524-532. doi: 10.1177/0956797611430953

Johnson, E. J., Haubl, G., & Keinan, A. (2007). Aspects of endowment: a query theory of value construction. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 33*(3), 461-474. doi: 10.1037/0278-7393.33.3.461

Just, M. A., & Carpenter, P. A. (1976). Eye fixations and cognitive processes. *Cognitive psychology, 8*(4), 441-480.

Just, M. A., & Carpenter, P. A. (1980). A theory of reading: From eye fixations to comprehension. *Psychological review, 87*(4), 329-354.

Kafkas, A., & Montaldi, D. (2011). Recognition memory strength is predicted by pupillary responses at encoding while fixation patterns distinguish recollection from familiarity. . *Q J Exp Psychol (Hove), 64*(10), 1971-1989. doi: 10.1080/17470218.2011.588335

Kahneman, D., & Frederick, S. (2002). Representativeness revisited: Attribute substitution in intuitive judgment. In T. Gilovich, D. Griffin & D. Kahneman (Eds.), *Heuristics and biases: The psychology of intuitive judgment*. New York: Cambridge University Press.

Kahneman, D., Knetsch, J. L., & Thaler, R. H. (1986). Fairness and the assumptions of economics. *Journal of Business, 59*(4), 285-300.

Karlson, K. B., Holm, A., & Breen, R. (2010). Total, Direct, and Indirect Effects in Logit Models. *CSER Working Paper No. 0003*.

Kelley, H. H., & Stahelski, A. J. (1970). Social interaction basis of cooperators' and competitors' beliefs about others. *Journal of personality and social psychology, 16*(1), 66-91.

Kieslich, P. J., & Hilbig, B. E. (2014). Cognitive conflict in social dilemmas: An analysis of response dynamics. *Judgment and Decision Making, 9*(6), 510-522.

Klein, R. A., Ratliff, K. A., Vianello, M., Adams Jr, R. B., Bahník, Š., Bernstein, M. J., . . . Nosek, B. A. (2014). Investigating variation in replicability: A “many labs” replication project. *Social psychology, 45*(3), 142-152. doi: 10.1027/a000001

Klein, S. B., Cosmides, L., Tooby, J., & Chance, S. (2002). Decisions and the evolution of memory: Multiple systems, multiple functions. *Psychological review, 109*(2), 306-329. doi: 10.1037//0033-295x.109.2.306

Knez, M. J., & Camerer, C. F. (1995). Outside options and social comparison in three-player ultimatum game experiments. *Games and Economic Behavior, 10*(1), 65-94.

Koole, S. L., & Lakens, D. (2012). Rewarding Replications: A Sure and Simple Way to Improve Psychological Science. *Perspectives on psychological science, 7*(6), 608-614. doi: 10.1177/1745691612462586

Krajbich, I., Armel, C., & Rangel, A. (2010). Visual fixations and the computation and comparison of value in simple choice. *Nature Neuroscience, 13*(10), 1292-1298. doi: 10.1038/nn.2635

Krajbich, I., Lu, D., Camerer, C., & Rangel, A. (2012). The attentional drift-diffusion model extends to simple purchasing decisions. *Front Psychol, 3*(193), 1-18. doi: 10.3389/fpsyg.2012.00193

Krajbich, I., & Rangel, A. (2011). Multialternative drift-diffusion model predicts the relationship between visual fixations and choice in value-based decisions. *Proceedings of the National Academy of Sciences, 108*(33), 13852-13857.

Krajbich, I., & Smith, S. M. (2015). Modeling Eye Movements and Response Times in Consumer Choice. *Journal of Agricultural & Food Industrial Organization, 13*(1), 55-72. doi: 10.1515/jafio-2015-0016

Kurzban, R., & DeScioli, P. (2008). Reciprocity in groups: information-seeking in a public goods game. *European Journal of Social Psychology, 38*(1), 139-158. doi: 10.1002/ejsp.443

10.1002/ejsp

Laughery, K. R., Alexander, J. F., & Lane, A. B. (1971). Recognition of human faces: effects of target exposure time, target position, pose position, and type of photograph. *Journal of Applied Psychology, 55*(5), 477-483.

Layous, K., Nelson, S. K., Oberle, E., Schonert-Reichl, K. A., & Lyubomirsky, S. (2012). Kindness counts: Prompting prosocial behavior in preadolescents boosts peer acceptance and well-being. *PLoS ONE, 7*(12), 1-3. doi: 10.1371/journal.pone.0051380

Lejarraga, T., Schulte-Mecklenbeck, M., & Smedema, D. (2017). The pyeTribe: Simultaneous eyetracking for economic games. *Behav Res Methods, 49*(5), 1769-1779. doi: 10.3758/s13428-016-0819-9

Liebrand, W. B., & McClintock, C. G. (1988). The ring measure of social values: a computerized procedure for assessing individual differences in information processing and social value orientation. *European Journal of Personality, 2*(3), 217-230.

Lim, S. L., O'Doherty, J. P., & Rangel, A. (2011). The decision value computations in the vmPFC and striatum use a relative value code that is guided by visual attention. *J Neurosci, 31*(37), 13214-13223. doi: 10.1523/JNEUROSCI.1246-11.2011

Maner, J. K., Gailliot, M. T., Rouby, D. A., & Miller, S. L. (2007). Can't take my eyes off you: Attentional adhesion to mates and rivals. *Journal of personality and social psychology, 93*(3), 389-401. doi: 10.1037/0022-3514.93.3.389

Manohar, S. G., & Husain, M. (2013). Attention as foraging for information and value. *Front Hum Neurosci, 7*(711), 1-16. doi: 10.3389/fnhum.2013.00711

Mantonakis, A., Rodero, P., Lesschaeve, I., & Hastie, R. (2009). Order in choice effects of serial position on preferences. *Psychological Science, 20*(11), 1309-1312.

Matz, S. C., Kosinski, M., Nave, G., & Stillwell, D. J. (2017). Psychological targeting as an effective approach to digital mass persuasion. *Proc Natl Acad Sci U S A, 114*(48), 12714-12719. doi: 10.1073/pnas.1710966114

McArthur, L. Z., & Baron, R. M. (1983). Toward an ecological theory of social perception. *Psychological review, 90*(3), 215-238.

McClintock, C. G. (1972). Social motivation—A set of propositions. *Behavioral Science, 17*(5), 438-454.

McNally, L., Brown, S. P., & Jackson, A. L. (2012). Cooperation and the evolution of intelligence. *Proceedings of the Royal Society B, 279*, 3027-3034. doi: 10.1098/rspb.2012.0206

Mealey, L., Daood, C., & Krage, M. (1996). Enhanced memory for faces of cheaters. *Ethology and Sociobiology, 17*(2), 119-128.

Mehl, B., & Buchner, A. (2008). No enhanced memory for faces of cheaters. *Evolution and Human Behavior, 29*(1), 35-41. doi: 10.1016/j.evolhumbehav.2007.08.001

Meißner, M., & Oll, J. (2017). The Promise of Eye-Tracking Methodology in Organizational Research. *Organizational Research Methods*, 1-28. doi: 10.1177/1094428117744882

Messick, D. M., & McClintock, C. G. (1968). Motivational bases of choice in experimental games. *Journal of Experimental Social Psychology, 4*(1), 1-25.

Miller, G. A. (2003). The cognitive revolution: a historical perspective. *Trends in cognitive sciences, 7*(3), 141-144. doi: 10.1016/s1364-6613(03)00029-9

Milosavljevic, M., Navalpakkam, V., Koch, C., & Rangel, A. (2012). Relative visual saliency differences induce sizable bias in consumer choice. *Journal of Consumer Psychology, 22*(1), 67-74. doi: 10.1016/j.jcps.2011.10.002

Mischel, W. (1973). Toward a cognitive social learning reconceptualization of personality. *Psychological review, 80*(4), 252-283.

Mischkowski, D., & Glöckner, A. (2016). Spontaneous cooperation for prosocials, but not for proselfs: Social value orientation moderates spontaneous cooperation behavior. *Sci Rep, 6*(21555), 1-5. doi: 10.1038/srep21555

Murdock Jr, B. B. (1962). The serial position effect of free recall. *Journal of Experimental Psychology, 65*(5), 482-488.

Nairne, J. S., Pandeirada, J. N., Gregory, K. J., & Van Arsdall, J. E. (2009). Adaptive memory: Fitness relevance and the hunter-gatherer mind. *Psychological Science, 20*(6), 740-746.

Navalpakkam, V., & Itti, L. (2005). Modeling the influence of task on attention. *Vision research, 45*(2), 205-231. doi: 10.1016/j.visres.2004.07.042

Newell, B. R., & Le Pelley, M. E. (2018). Perceptual but not complex moral judgments can be biased by exploiting the dynamics of eye-gaze. *Journal of Experimental Psychology: General, 147*(3), 409-417. doi: 10.1037/xge0000386

Nittono, H., & Wada, Y. (2009). Gaze shifts do not affect preference judgments of graphic patterns. *Perceptual and motor skills, 109*(1), 79-94.

Nosek, B. A., & Lakens, D. (2014). Registered reports: A method to increase the credibility of published results. *Social psychology, 45*(3), 137-141. doi: 10.1027/a000001

Nosek, B. A., Spies, J. R., & Motyl, M. (2012). Scientific utopia: II. Restructuring incentives and practices to promote truth over publishability. *Perspectives on psychological science, 7*(6), 615-631.

Orquin, J. L., Ashby, N. J. S., & Clarke, A. D. F. (2016). Areas of Interest as a Signal Detection Problem in Behavioral Eye-Tracking Research. *Journal of Behavioral Decision Making, 29*(2-3), 103-115. doi: 10.1002/bdm.1867

Orquin, J. L., & Mueller Loose, S. (2013). Attention and choice: a review on eye movements in decision making. *Acta psychologica, 144*(1), 190-206. doi: 10.1016/j.actpsy.2013.06.003

Osborne, M. J., & Rubinstein, A. (1994). *A course in game theory*: MIT press.

Pärnamets, P., Johansson, P., Hall, L., Balkenius, C., Spivey, M. J., & Richardson, D. C. (2015). Biasing moral decisions by exploiting the dynamics of eye gaze. *Proceedings of the National Academy of Sciences, 112*(13), 4170-4175. doi: 10.1073/pnas.1415250112

Payne, J. W., Bettman, J. R., & Johnson, E. J. (1993). *The adaptive decision maker*. Cambridge, England: Cambridge University Press.

Penner, L. A., Fritzsche, B. A., Craiger, J. P., & Freifeld, T. R. (1995). Measuring the prosocial personality. *Advances in personality assessment, 10*, 147-163.

Pittarello, A., Leib, M., Gordon-Hecker, T., & Shalvi, S. (2015). Justifications Shape Ethical Blind Spots. *Psychological Science, 26*(6), 794-804. doi: 10.1177/0956797615571018

Pletzer, J. L., Balliet, D., Joireman, J., Kuhlman, D. M., Voelpel, S. C., & Van Lange, P. A. (2018). Social Value Orientation, Expectations, and Cooperation in Social Dilemmas: A Meta-analysis. *European Journal of Personality, 32*(1), 62-83. doi: 10.1002/per.2139

10.1002/per

Polonio, L., Di Guida, S., & Coricelli, G. (2015). Strategic sophistication and attention in games: An eye-tracking study. *Games and Economic Behavior, 94*, 80-96. doi: 10.1016/j.geb.2015.09.003

Popper, K. (2005). *The logic of scientific discovery*: Routledge.

Posner, M. I. (1980). Orienting of attention. *Q J Exp Psychol (Hove), 32*(1), 3-25. doi: 10.1080/00335558008248231

Pruitt, D. G., & Kimmel, M. J. (1977). Twenty years of experimental gaming: Critique, synthesis, and suggestions for the future. *Annual review of psychology, 28*(1), 363-392.

Rabin, M. (1993). Incorporating Fairness into Game Theory and Economics. *American Economic Review, 83*(5), 1281-1302.

Rand, D. G., Greene, J. D., & Nowak, M. A. (2012). Spontaneous giving and calculated greed. *Nature, 489*(7416), 427-430. doi: 10.1038/nature11467

Rapoport, A., & Chammah, A. M. (1965). *Prisoner's dilemma: A study in conflict and cooperation* (Vol. 165): University of Michigan press.

Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological Bulletin, 124*(3), 372-420.

Reips, U.-D. (2002). Standards for Internet-Based Experimenting. *Experimental Psychology (formerly Zeitschrift für Experimentelle Psychologie), 49*(4), 243-256. doi: 10.1027//1618-3169.49.4.243

Reutskaja, E., Nagel, R., Camerer, C. F., & Rangel, A. (2011). Search dynamics in consumer choice under time pressure: An eye-tracking study. *American Economic Review, 101*(2), 900-926. doi: 10.1257/aer

Rubin, D. C., & Wenzel, A. E. (1996). One hundred years of forgetting: A quantitative description of retention. *Psychological review, 103*(4), 734-760.

Rushton, J. P., Chrisjohn, R. D., & Fekken, G. C. (1981). The altruistic personality and the self-report altruism scale. *Personality and Individual Differences, 2*(4), 293-302.

Russo, J. E. (2011). Eye fixations as a process trace. In M. Schulte-Mecklenbeck, A. Kühberger & R. Ranyard (Eds.), *A handbook of process tracing methods for decision research: A critical review and user's guide* (pp. 43-64): Psychology Press.

Russo, J. E., & Leclerc, F. (1994). An eye-fixation analysis of choice processes for consumer nondurables. *Journal of Consumer Research, 21*(2), 274-290.

Salvucci, D. D., & Goldberg, J. H. (2000). Identifying fixation and saccades in eye tracking protocols *Proceedings of the 2000 symposium on eye tracking research & application* (pp. 71-78). Palm Beach Gardens, FL.

Schimmack, U. (2012). The ironic effect of significant results on the credibility of multiple-study articles. *Psychological methods, 17*(4), 551-566. doi: 10.1037/a0029487

Schotter, E. R., Berry, R. W., McKenzie, C. R. M., & Rayner, K. (2010). Gaze bias: Selective encoding and liking effects. *Visual Cognition, 18*(8), 1113-1132. doi: 10.1080/13506281003668900

Schützwohl, A. (2006). Sex differences in jealousy: Information search and cognitive preoccupation. *Personality and Individual Differences, 40*(2), 285-292. doi: 10.1016/j.paid.2005.06.024

Schützwohl, A., & Koch, S. (2004). Sex differences in jealousy: The recall of cues to sexual and emotional infidelity in personally more and less threatening context conditions. *Evolution and Human Behavior, 25*(4), 249-257. doi: 10.1016/j.evolhumbehav.2004.03.006

Sharot, T., Velasquez, C. M., & Dolan, R. J. (2010). Do decisions shape preference? Evidence from blind choice. *Psychological Science, 21*(9), 1231-1235. doi: 10.1177/0956797610379235

Shen, L., & Urminsky, O. (2013). Making sense of nonsense: the visual salience of units determines sensitivity to magnitude. *Psychological Science, 24*(3), 297-304. doi: 10.1177/0956797612451470

Shimojo, S., Simion, C., Shimojo, E., & Scheier, C. (2003). Gaze bias both reflects and influences preference. *Nature Neuroscience, 6*(12), 1317-1322. doi: 10.1038/nn1150

Simon, D., & Spiller, S. A. (2016). The Elasticity of Preferences. *Psychological Science, 27*(12), 1588-1599. doi: 10.1177/0956797616666501

Simon, H. A. (1972). Theories of bounded rationality. *Decision and organization, 1*(1), 161-176.

Skulmowski, A., Bunge, A., Kaspar, K., & Pipa, G. (2014). Forced-choice decision-making in modified trolley dilemma situations: a virtual reality and eye tracking study. *Frontiers in behavioral neuroscience, 8*(426), 1-16. doi: 10.3389/fnbeh.2014.00426

Smeesters, D., Warlop, L., Van Avermaet, E., Corneille, O., & Yzerbyt, V. (2003). Do not prime hawks with doves: The interplay of construct activation and consistency of social value orientation on cooperative behavior. *Journal of personality and social psychology, 84*(5), 972-987. doi: 10.1037/0022-3514.84.5.972

Smith, A. (1976). *Theory of Moral Sentiments* Clifton, NJ: Kelley.

Sobel, M. E. (1982). Asymptotic confidence intervals for indirect effects in structural equation models. *Sociological methodology, 13*, 290-312.

Stevens, J. R., Volstorf, J., Schooler, L. J., & Rieskamp, J. (2011). Forgetting constrains the emergence of cooperative decision strategies. *Frontiers in psychology, 1*(235), 1-12. doi: 10.3389/fpsyg.2010.00235

Stewart, A. J., & Plotkin, J. B. (2016). Small groups and long memories promote cooperation. *Sci Rep, 6*(26880), 1-11. doi: 10.1038/srep26889

Stewart, N., Gächter, S., Noguchi, T., & Mullett, T. L. (2016). Eye Movements in Strategic Choice. *Journal of Behavioral Decision Making, 29*(2-3), 137-156. doi: 10.1002/bdm.1901

Störmer, V. S., & Alvarez, G. A. (2016). Attention Alters Perceived Attractiveness. *Psychological Science, 27*(4), 563-571. doi: 10.1177/0956797616630964

Terhune, K. (1968). Motives, situation, and interpersonal conflict within prisoner's dilemma. *Journal of personality and social psychology, 8*(3), 1-24.

Tinghög, G., Andersson, D., Bonn, C., Böttiger, H., Josephson, C., Lundgren, G., . . . Johannesson, M. (2013). Intuition and cooperation reconsidered. *Nature, 498*(7452), 1-3. doi: 10.1038/nature12194

Towal, R. B., Mormann, M., & Koch, C. (2013). Simultaneous modeling of visual saliency and value computation improves predictions of economic choice. *Proc Natl Acad Sci U S A, 110*(40), 3858-3867. doi: 10.1073/pnas.1304429110

Trivers, R. L. (1971). The evolution of reciprocal altruism *The Quarterly review of biology, 46*(1), 35-57.

Van Lange, P. A. (1992). Confidence in expectations: A test of the triangle hypothesis. *European Journal of Personality, 6*(5), 371-379.

Van Lange, P. A. (1999). The pursuit of joint outcomes and equality in outcomes: An integrative model of social value orientation. *Journal of personality and social psychology, 77*(2), 337-349.

Verplaetse, J., Vanneste, S., & Braeckman, J. (2007). You can judge a book by its cover: the sequel.: A kernel of truth in predictive cheating detection. *Evolution and Human Behavior, 28*(4), 260-271. doi: 10.1016/j.evolhumbehav.2007.04.006

Volstorf, J., Rieskamp, J., & Stevens, J. R. (2011). The Good, the Bad, and the Rare: Memory for Partners in Social Interactions. *PLoS ONE, 6*(4), e18945. doi: 10.1371/journal.pone.0018945

Wang, J. T. Y., Spezio, M., & Camerer, C. F. (2010). Pinocchio's pupil: using eyetracking and pupil dilation to understand truth telling and deception in sender-receiver games. *American Economic Review, 100*(3), 984-1007.

Wedel, M., & Pieters, R. (2008). Eye Tracking for Visual Marketing. *Foundations and Trends® in Marketing, 1*(4), 231-320. doi: 10.1561/1700000011

Wicherts, J. M., Borsboom, D., Kats, J., & Molenaar, D. (2006). The poor availability of psychological research data for reanalysis. *American Psychologist, 61*(7), 726-728.

Wilmer, J. B., Germine, L., Chabris, C. F., Chatterjee, G., Williams, M., Loken, E., . . . Duchaine, B. (2010). Human face recognition ability is specific and highly heritable. *Proceedings of the National Academy of Sciences, 107*(11), 5238-5241. doi: 10.1073/pnas.0913053107

Wright, R. D., & Ward, L. M. (2008). *Orienting of attention* Oxford University Press.

Yamagishi, T., Tanida, S., Mashima, R., Shimoma, E., & Kanazawa, S. (2003). You can judge a book by its cover: Evidence that cheaters may look different from cooperators. *Evolution and Human Behavior, 24*(4), 290-301. doi: 10.1016/S1090-5138(03)00035-7

Yarbus, A. L. (1967). Eye movements during perception of complex objects *Eye movements and vision* (pp. 171-211). US: Springer.

Supplement: Chapter I

Table S1

List of money allocation tasks

	Study 1					Study 2					Study 3				
	Option A		Option B			Option A		Option B			Option A		Option B		
Item #	Self	Other	Self	Other	CB	Self	Other	Self	Other	CB	Self	Other	Self	Other	CB
1	5.25	4.00	6.02	2.95	0.73	5.25	4.00	6.02	2.95	0.73	5.25	4.00	6.02	2.95	0.73
2	4.30	1.49	3.42	2.87	0.64	4.30	1.49	3.42	2.87	0.64	2.70	1.93	3.62	0.47	0.63
3	2.42	1.71	3.32	0.48	0.73	2.42	1.71	3.32	0.48	0.73	3.79	3.49	4.49	2.22	0.55
4	5.93	2.86	5.32	3.99	0.54	5.93	2.86	5.32	3.99	0.54	4.49	2.79	3.80	3.70	0.76
5	4.27	3.60	4.88	2.43	0.52	4.27	3.60	4.88	2.43	0.52	5.59	2.66	5.02	3.76	0.52
6	2.49	1.66	3.35	0.45	0.71	2.49	1.66	3.35	0.45	0.71	4.30	1.49	3.42	2.87	0.64
7	4.49	2.79	3.80	3.70	0.76	4.49	2.79	3.80	3.70	0.76	-	-	-	-	-
8	2.70	1.93	3.62	0.47	0.63	2.70	1.93	3.62	0.47	0.63	-	-	-	-	-
9	5.59	2.66	5.02	3.76	0.52	-	-	-	-	-	-	-	-	-	-
10	3.79	3.49	4.49	2.22	0.55	-	-	-	-	-	-	-	-	-	-

Note. We report the possible payoffs for the participant (self) and the interaction partner (other) depending on whether option A or B is chosen and the cost-benefit ratio for each item. In Study 2 and 3 each money allocation problem was shown with two interaction partners.
CB = cost-benefit ratio

Study 1

Study 2

Study 3

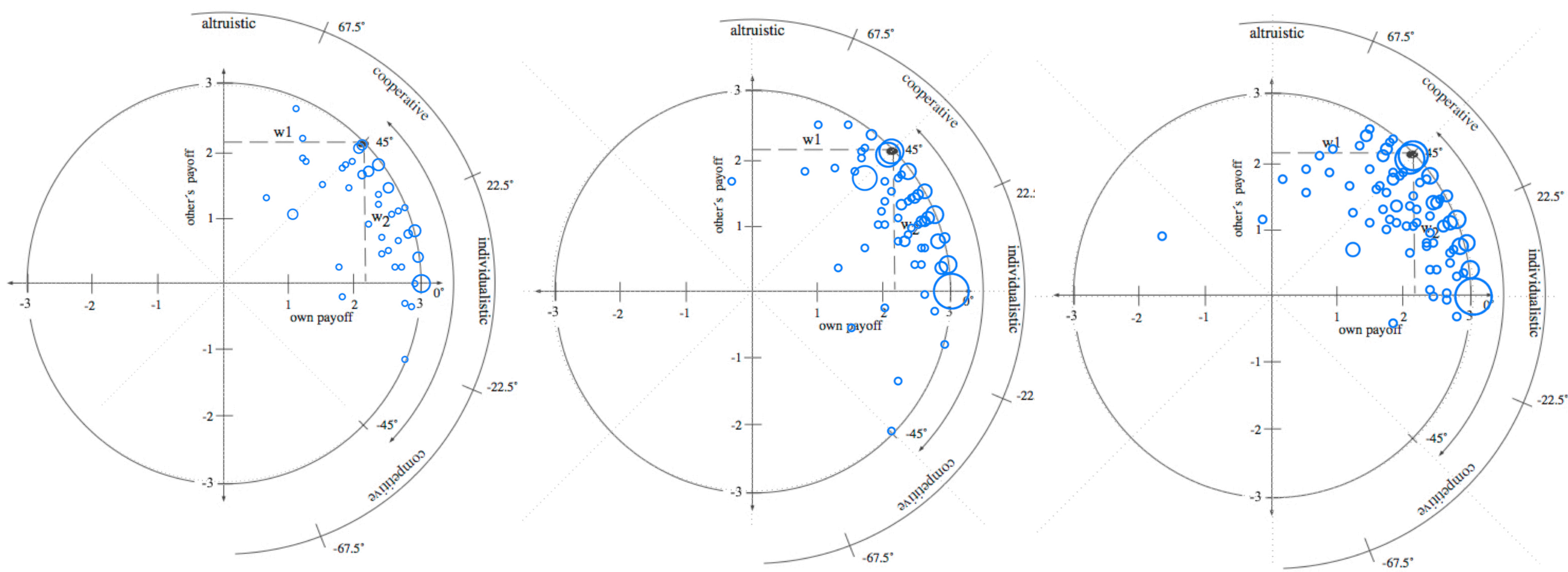

Figure S1. Graphical representation of Social Value Orientations, adapted from Liebrand and McClintock (1988) including the distribution of participants' SVO angles for all studies.

Study 2a

Method

Procedure.

Implicit memory phase. Unfortunately, results in Study 2a suggested that a substantial proportion of participants misunderstood the implicit memory task (see Figure S2). A first indication for this lack of understanding was a difference in the number of choices of the partner that had behaved prosocial during encoding depending on the counterbalance condition participants had randomly been assigned to. We counterbalanced whether the prosocial or individualistic interaction partner was presented on the left or right side with the money allocation problem presented in the middle. This resulted in two groups of participants, one for which the prosocial partner was always on the same side as the prosocial option in the money allocation problem (i.e. the option that would maximize the participants' payoff) and one for which the individualistic partner was presented on the same side as the more prosocial option. The group for which the prosocial partner was presented at the same side as the prosocial option chose the prosocial partner in 81.65% of the trials while the other group did so in only 43.49% if the trials. This difference between the groups can be explained if at least some participants misunderstood the task and thought that they will receive the option that is at the same side as the interaction partner they choose, because for the first group it would maximize their payoff if they chose the prosocial partner while for the second group it would maximize payoff to choose the individualistic partner. In Study 2b, we adapted the design of the task to accurately measure implicit memory performance.

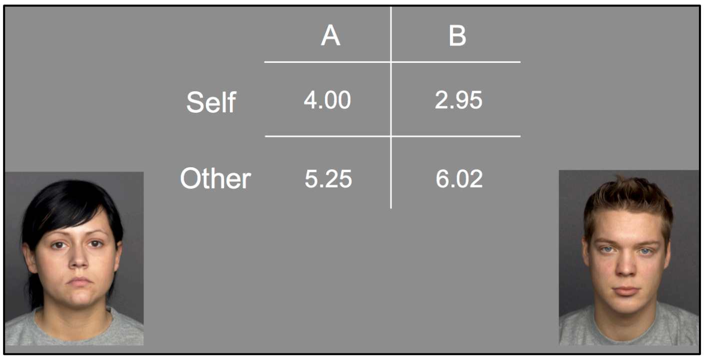

Figure S2. Presentation of the implicit memory phase in Study 2.

Data analysis. Studying the attentional processes of participants, the different pieces of information were separated into Areas of Interest (AOI). For a graphical presentation of the AOIs' positions, please see Figure S3. Further, Table S2 includes descriptive statistics on the direction of participants' first fixations to these different AOIs.

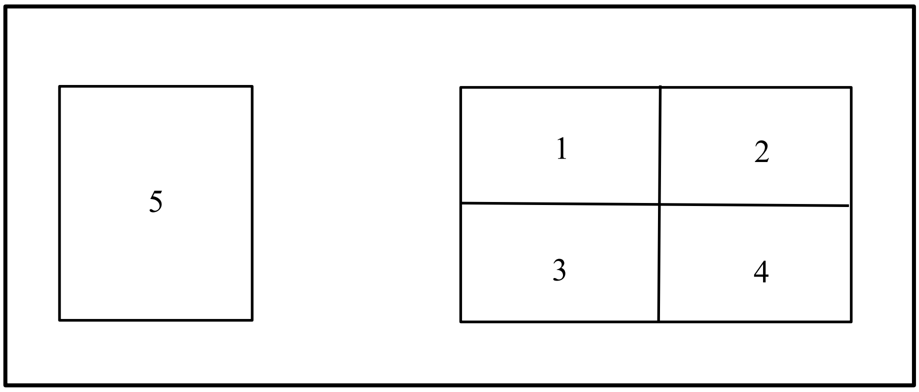

Figure S3. Numbering of Areas of Interest. Numbers 1- 4 refer to presented payoffs and number 5 refers to presented picture of face.

Table S2

Direction of first fixations depending on AOIs content.

		Percent of first fixations directed towards AOI	
	Content of AOI	Own payoffs top row	Other's payoffs top row
AOI 1	Payoff	42.27 %	34.95 %
AOI 2	Payoff	21.92 %	21.34 %
AOI 3	Payoff	10.85 %	15.89 %
AOI 4	Payoff	9.79 %	13.71 %
AOI 5	Face	15.17 %	14.11 %

Note. AOI = Areas of Interest. See Figure S3 for the respective position of the AOI.

Study 2b & 3

Method

Procedure. The procedure of the implicit memory phase was adapted for Study 2b and 3. Please see Figure S4 for the adapted procedure.

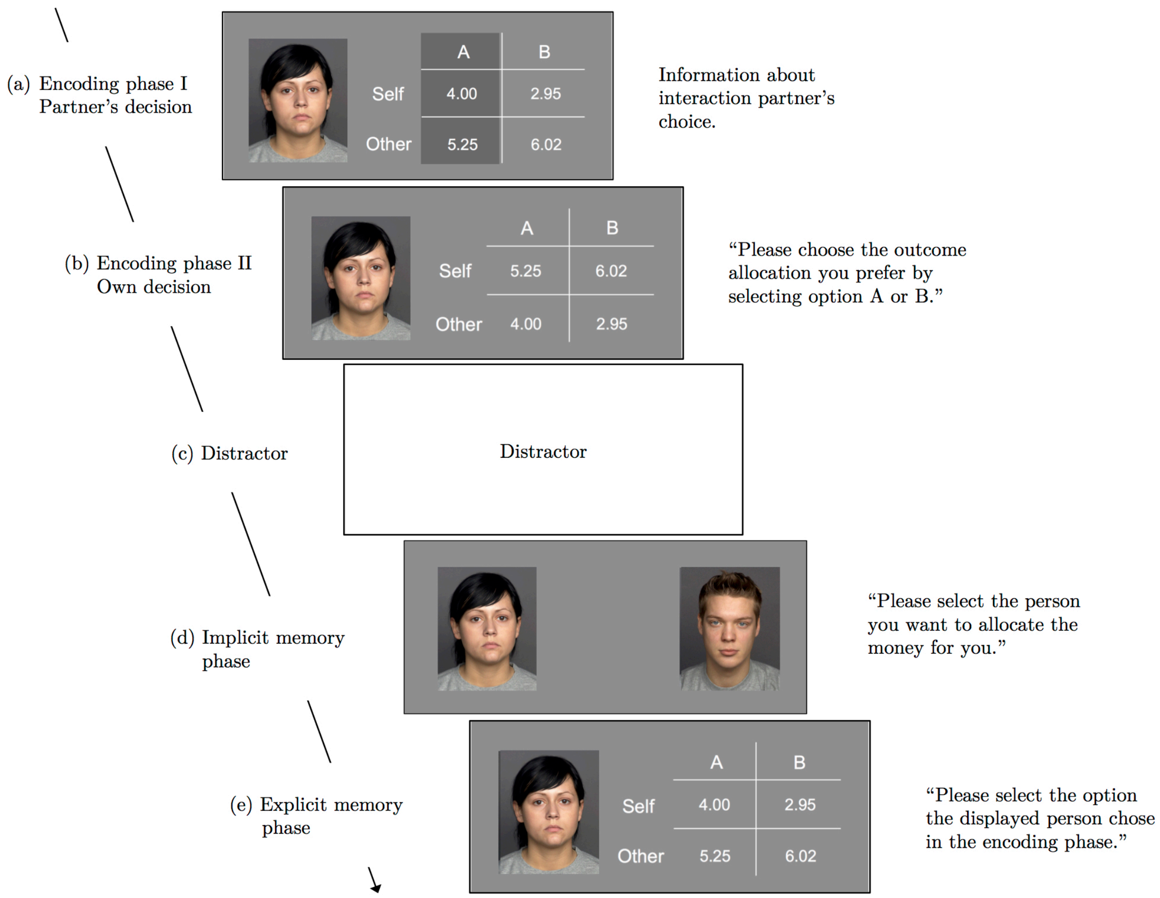

Figure S4. Experimental procedure of Study 2b and 3. (a) Partner's decision: Observation of interaction partner's choice. In this example the partner chose option A. (b) Own decision: Participant could choose how to distribute money between himself and the displayed partner by either choosing option A or B. (c) Distractor: Presentation of distractor task. (d) Implicit memory phase: Participant could choose one partner to allocate the money for them. (e) Explicit memory phase: Recall of the displayed person's behavior.

Table S3

Explicit memory performance predicted by SVO angle (including controls)

	β (correct explicit memory)									
	Short-term								Long-term	
	Study 1		Study 2a		Study 3		Meta-Analysis		Study 2b	
SVO angle	0.28^{*}	(2.20)	0.26^{*}	(2.11)	0.04	(0.60)	0.17^{**}	(2.80)	0.10	(1.21)
Prosocial partner	-0.11	(-0.86)	0.07	(0.33)	-0.06	(1.29)	0.04	(0.71)	0.14	(1.43)
Female participant	-0.00	(-0.01)	0.03	(0.68)	0.10	(-0.70)	-0.01	(-0.11)	-0.14^{+}	(-1.65)
Female partner	-0.02	(-0.21)	0.19^{***}	(3.91)	-0.04	(-0.78)	0.06^{+}	(1.91)	0.11^{*}	(2.19)
Risk aversion	-0.13	(-0.90)	-0.10	(-0.94)	-		-0.04	(-0.64)	-0.10	(-1.49)
Attractiveness	0.12	(1.13)	0.05	(1.01)	-0.18^{*}	(-2.43)	0.07	(1.16)	-0.06	(-1.16)
Cost-benefit ratio	0.19^{*}	(2.47)	0.14^{*}	(2.51)	-0.21^{**}	(-3.22)	0.05	(1.51)	0.11^{+}	(1.89)
Memory ability	-		0.23^{*}	(2.33)	-		-		0.10	(1.37)
Empathy	-		-		0.10	(1.37)	-		-	
Online study	-		-		-		-0.07	(-0.97)	-	
Study number	-		-		-		-0.20	(-2.50)	-	
Constant	1.20^{***}	(7.54)	0.97^{***}	(7.81)	0.53^{***}	(6.08)	0.81	(11.99)	0.48^{***}	(6.16)
Observations	610		1760		1608		3978		1424	

Note. Standardized coefficients are reported; z statistics in parentheses, p values two-sided, * $p < .05$, ** $p < .01$.

Table S4

Prosocial choices predicted by SVO angle

	β (prosocial choice)					
	Study 1		Study 2a		Study 3	
SVO angle	1.88***	(5.14)	2.57***	(6.53)	1.63***	(4.13)
Constant	0.29	(1.01)	0.46	(1.63)	0.33	(1.40)
Observations	4270		17600		11256	

Note. Standardized coefficients are reported; *z* statistics in parentheses, ** $p < .01$, *** $p < .001$.

Table S5

Decomposition of total effect of SVO angle on explicit memory performance into direct and indirect effect via response time (while participants makes own decision)

	Study 1	
	β (correct explicit memory)	
Total effect (*c*)		
SVO angle	0.28^{*}	(2.06)
Direct effect (*c'*)		
SVO angle	0.29^{*}	(2.05)
(controlling for response time)		
Indirect effect ($a \times b$)		
SVO angle	-0.00	(-0.13)
(via response time)		
Observations	610	

Note. Standardized coefficients are reported, z statistics in parentheses. Control variables are included. For the indirect effect, standard errors are bootstrapped with 1000 repetitions. * $p < .05$, ** $p < .01$.

Table S6

Explicit memory performance predicted by SVO angle (no controls)

	β (correct explicit memory)									
	Short-term								Long-term	
	Study 1		Study 2a		Study 3		Meta-Analysis		Study 2b	
SVO angle	0.31^{*}	(2.43)	0.26^{*}	(2.24)	0.002	(0.76)	0.13^{*}	(2.03)	0.08	(1.12)
Constant	1.18^{***}	(7.60)	0.96^{***}	(7.66)	0.46^{***}	(4.11)	0.81^{***}	(11.81)	0.47^{***}	(5.94)
Observations	610		1760		1608		3978		1440	

Note. Standardized coefficients are reported; z statistics in parentheses, * $p < .05$, *** $p < .001$.

Table S7

Fixation number / Attention to other's payoffs during encoding predicted by SVO angle

	Study 2a			
	Fixation number (log)		Proportion of attention to other's payoff	
	Simple effect	Including controls	Simple effect	Including controls
SVO angle	0.14^{+} (1.65)	0.12 (1.23)	0.12 (1.34)	0.16^{**} (2.95)
Prosocial partner	-	-0.02^{+} (-1.90)	-	0.00 (0.70)
Female participant	-	0.03 (0.36)	-	0.10^{+} (1.86)
Female partner	-	0.01 (0.74)	-	0.02^{***} (3.69)
Risk aversion	-	0.09 (1.00)	-	-0.03 (-0.41)
Attractiveness	-	-0.01 (-1.35)	-	0.01^{+} (1.83)
Cost-benefit ratio	-	-0.03^{**} (-3.13)	-	0.01 (0.81)
Memory ability	-	0.27^{***} (3.45)	-	0.06 (1.08)
Position of other's payoff (1 = top row)	-	-	-	0.79^{***} (14.72)
Constant	-0.00 (-0.00)	-0.00 (-0.00)	0.00 (0.00)	0.00 (0.00)
Observations	1616			

Note. Standardized coefficients are reported; *z* statistics in parentheses, $^{+}p < .10$, $^{**}p < .01$, $^{***}p < .001$

Table S8

Study 2a: Explicit memory performance predicted by fixation number / attention to other's payoffs / attention to other's face

	β (correct explicit memory)					
	Model 1		Model 2		Model 3	
Fixation number (log)	0.40^{***}	(5.03)	-		-	
Attention to other's payoffs	-		0.24^{**}	(2.78)	-	
Attention to other's face (log)	-		-		0.17^{*}	(2.04)
SVO angle	0.15	(1.47)	0.17	(1.37)	0.21	(1.62)
Prosocial partner	0.01	(0.07)	0.001	(0.01)	-0.02	(-0.15)
Female participant	0.05	(0.48)	0.06	(0.55)	0.04	(0.35)
Female partner	0.18^{***}	(3.51)	0.18^{**}	(3.44)	0.20^{**}	(3.46)
Risk aversion	-0.09	(-0.94)	-0.0004	(-0.00)	0.01	(0.12)
Attractiveness	0.06	(1.18)	0.05	(1.03)	0.06	(1.05)
Cost-benefit ratio	0.14^{*}	(2.43)	0.13^{*}	(2.27)	0.11^{+}	(1.86)
Memory ability	0.15	(1.59)	0.25^{*}	(2.52)	0.24^{*}	(2.31)
Constant	1.00^{***}	(8.38)	1.01^{***}	(7.67)	1.05	(7.84)
Observations	1616		1616		1537	

Note. Standardized coefficients are reported; z statistics in parentheses, ^{+}p <.10, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$.

Table S9

Decomposition of total effect of SVO angle on explicit memory performance into direct and indirect effect via response time (while receiving feedback about the partner's decision).

	β (correct explicit memory)		
	Study 1	Study 2a	Meta-Analysis
Total effect (c)			
SVO angle	0.27^{*} (2.07)	0.20^{+} (1.76)	0.09 (1.26)
Direct effect (c')			
SVO angle (controlling for response time)	0.20 (1.41)	0.15 (1.29)	0.05 (0.74)
Indirect effect ($a \times b$)			
SVO angle (via response time)	0.08^{+} (1.67)	0.05^{*} (2.53)	0.04^{*} (2.59)
Observations	610	1616	3850

Note. Standardized coefficients are reported, z statistics in parentheses. Control variables are included. For the Meta-analysis we additionally control for study type and study number. For the indirect effect, standard errors are bootstrapped with 1000 repetitions. ^{+}p <.10, $^{*}p$ < .05.

Supplement: Chapter II

Table S10

Payoffs and cooperation index for all items

Version 1

Item #	Reward	Punishment	Temptation	Sucker	Cooperation Index (R-P) / (T-S)
1	31	25	61	1	0.1
2	36	18	62	2	0.3
3	42	12	63	3	0.5
4	48	6	64	4	0.7
5	57	3	65	5	0.9
6	25	13	61	1	0.2
7	36	18	51	6	0.4
8	46	12	59	3	0.6
9	54	8	63	5	0.8
10	68	4	72	8	1

Version 2

Item #	Reward	Punishment	Temptation	Sucker	Cooperation Index (R-P) / (T-S)
1	31	25	61	1	0.1
2	34	27	76	1	0
3	25	13	61	1	0.2
4	28	17	57	2	0.2
5	36	18	62	2	0.3
6	29	11	62	3	0.3
7	35	19	51	6	0.35
8	43	12	81	4	0.4
9	49	13	82	10	0.5
10	42	12	63	3	0.5

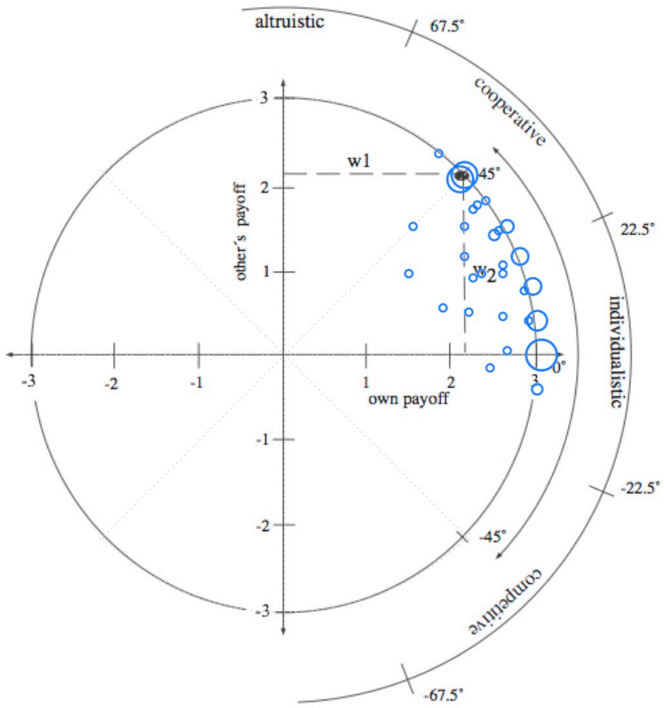

Figure S5. Graphical representation of participants' SVO angles. The weight assigned to own outcomes (w_1) and other's outcomes (w_2) determine the degree of the angle.

Table S11

Cooperative choice predicted by SVO angle and Cooperation Bias

	Cooperative choice (OR)					
	Without controls		Without controls		With controls	
SVO angle	1.06^{**}	(3.29)	-		1.06^{***}	(3.41)
Cooperation index	-		-		68.84^{***}	(5.87)
Cooperation Bias	-		1.04	(0.19)	0.96	(-0.20)
Trial	-		-		0.95	(-1.27)
Constant	0.55	(-1.36)	1.55	(1.32)	0.17^{**}	(-3.11)
Observations			620			

Note. Odds ratios are reported; *z* statistics in parentheses, ** $p < .01$, *** $p < .001$.

Table S12

Response time and fixation number predicted by SVO angle

	Response time (log)				Fixation number (log)			
	Without controls		With controls		Without controls		With controls	
SVO angle	0.02	(0.26)	0.02	(0.27)	0.05	(0.55)	0.05	(0.55)
Cooperation Index	-		0.00	(0.02)	-		0.00	(0.00)
Cooperation Bias	-		0.06^{*}	(2.02)	-		0.06^{*}	(2.12)
Trial number	-		-0.36^{***}	(-9.06)	-		-0.31^{***}	(-8.09)
Constant	-0.04	(-0.45)	-0.04	(-0.52)	-0.04	(-0.53)	-0.05	(-0.58)
Observations	620							

Note. Standardized coefficients are reported; z statistics in parentheses, $^{*}p < .05$, $^{***}p < .001$.

Table S13

Proportion of attention to other's payoffs predicted by SVO angle

	Attention to other's payoffs				Attention to cooperative strategy			
	Without controls		With controls		Without controls		With controls	
SVO angle	0.21^{*}	(2.54)	0.21^{**}	(2.56)	0.20^{**}	(2.93)	0.20^{**}	(2.94)
Cooperation index	-		0.04	(0.96)	-		0.06	(1.33)
Trial number	-		-0.04	(-1.38)	-		-0.03	(-0.73)
Constant	0.03	(0.31)	0.03	(0.30)	-0.01	(-0.10)	-0.01	(-0.11)
Observations	620				620			

Note. Standardized coefficients are reported, z statistics in parentheses; * < .05, ** < .01.

Table S14

Response time and fixation number predicted by type of choice

	Response time (log)				Fixation number (log)			
	Without controls		With controls		Without controls		With controls	
Cooperative choice	-0.09^{*}	(-2.01)	-0.12^{**}	(-2.89)	-0.09^{*}	(-2.01)	-0.12^{**}	(-2.83)
SVO angle	-		0.04	0.47	-		0.09	(1.01)
Cooperative choice * SVO angle	-		-0.12^{**}	(-3.28)	-		-0.10	(-2.71)
Cooperation index	-		0.03	(0.77)	-		0.02	(0.80)
Trial number	-		-0.39^{***}	(-9.66)	-		-0.32^{***}	(-8.04)
Constant	-0.03	(-0.38)	0.001	(0.02)	-0.04	(-0.54)	-0.02	(-0.24)
Observations	620							

Note. Standardized coefficients are reported, z statistics in parentheses, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$.

Table S15

Attention to cooperative strategy predicted by type of choice

	Attention to cooperative strategy			
	Without controls		With controls	
Cooperative choice	0.24***	(4.90)	0.24***	(4.92)
Cooperation index	-		-0.01	(-0.15)
Trial number	-		-0.01	(-0.14)
Constant	-0.004	(-0.06)	-0.004	(-0.06)
Observations	620			

Note. Standardized coefficients are reported, *z* statistics in parentheses, * $p < .05$, ** $p < .01$, *** $p < .001$

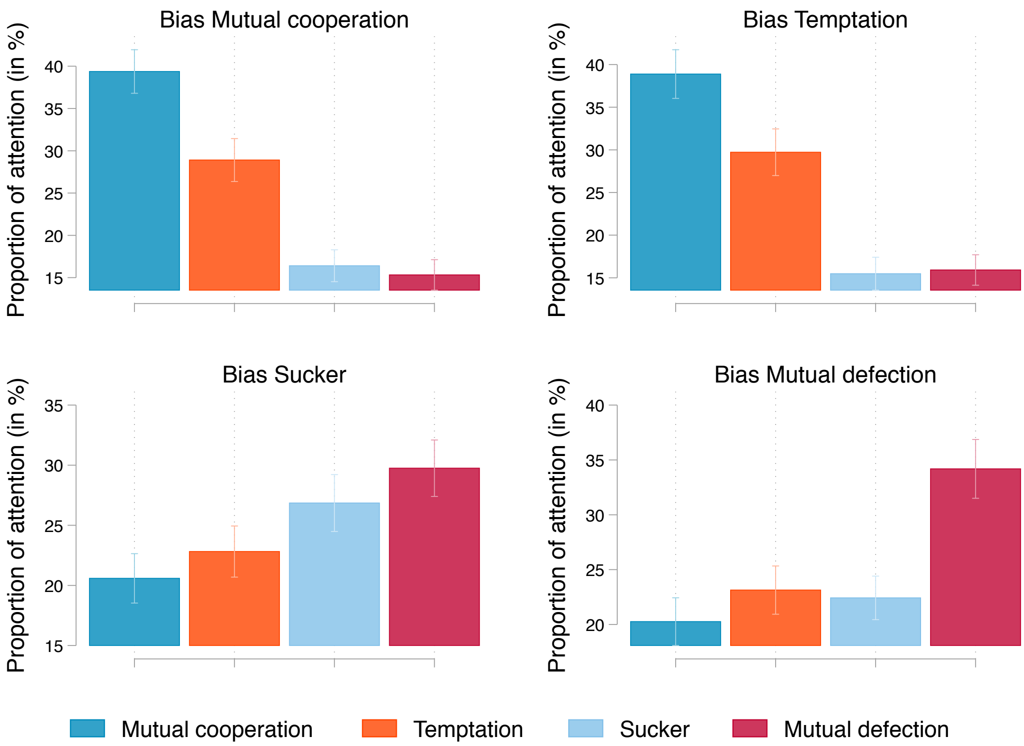

Figure S6. Proportion of attention directed to the different payoff combinations depending on location bias. Error bars indicate 95% confidence intervals.

Supplement: Chapter III

Table S16

Study 1: Choice of right option predicted by last fixation for self-determined (A), interrupted (B) and all trials (C). Separate analysis for other-regarding and moral choices.

	(A) Self-determined OR (right option)		(B) Interrupted OR (right option)		(C) All trials OR (right option)	
	Social	Moral	Social	Moral	Social	Moral
Last fixation	7.45^{***}	12.58^{***}	2.89^{***}	4.03^{***}	3.79^{***}	5.06^{***}
right	(8.55)	(11.60)	(7.70)	(9.93)	(11.75)	(15.11)
Relative time	4.44^{***}	5.72^{***}	2.02^{***}	2.84^{***}	2.22^{***}	2.82^{***}
advantage right	(7.43)	(10.65)	(5.67)	(7.05)	(8.91)	(10.72)
SVO Angle	1.00	-	1.00	-	1.00	-
	(-0.22)		(1.00)		(1.10)	
SVO Angle ×	1.00	-	1.00	-	1.00	-
Last fixation	(0.26)		(-0.55)		(-1.01)	
Confidence	0.97	0.96	0.93^{*}	0.98	0.93^{*}	0.97
	(-0.53)	(-0.76)	(-2.05)	(-0.63)	(-2.44)	(-1.00)
Trial number	0.99^{*}	1.00	1.00	1.00	1.00	1.00
	(-2.03)	(-0.38)	(1.46)	(0.60)	(0.85)	(1.06)
Constant	1.15	1.05	0.82^{**}	0.83^{**}	0.92	0.92
	(1.21)	(0.47)	(-3.11)	(-2.91)	(-1.76)	(-1.61)
Observations	1179	1329	1404	1448	3243	3368

Note. Odds Ratios; *z* statistics in parentheses, * $p < .05$, ** $p < .01$, *** $p < .001$. All variables are centered.

Table S17

Study 1: Choice of right option predicted by last fixation and interrupted trial for other-regarding choices (A), moral choices (B) and all trials (C).

	(A) Other-regarding OR (right option)		(B) Moral OR (right option)		(C) All trials OR (right option)	
Last fixation right	4.48***	(11.19)	6.63***	(15.63)	4.51***	(16.41)
Interrupted	0.77*	(-2.26)	0.78*	(-2.40)	0.76***	(-4.00)
Last fixation × Interrupted	0.50**	(-3.05)	0.41***	(-3.98)	0.63**	(-3.15)
Relative time advantage right	3.02***	(8.95)	4.13***	(14.36)	2.39***	(10.36)
Confidence	0.94+	(-1.88)	0.97	(-0.86)	0.94**	(-3.08)
Trial number	1.00	(-0.12)	1.00	(0.35)	1.00	(0.65)
Constant	0.93	(-1.24)	0.91	(-1.62)	0.94	(-1.66)
Observations	2675		2777		6724	

Note. Odds Ratios; *z* statistics in parentheses, * $p < .05$, ** $p < .01$, *** $p < .001$. All variables are centered.

Table S18

Study 1: Comparison of other-regarding and moral choices. Choice of right option predicted by last fixation for self-determined (A), interrupted (B) and all trials (C).

	(A) Self-determined OR (right option)		(B) Interrupted OR (right option)		(C) All trials OR (right option)	
Last fixation right	9.43^{***}	(11.66)	3.44^{***}	(10.83)	4.37^{***}	(15.89)
Moral item	0.96	(-0.35)	1.00	(-0.05)	1.00	(0.04)
Moral item × Last fixation	1.61^{*}	(2.29)	1.28	(1.54)	1.26^{*}	(2.02)
Relative time advantage right	4.87^{***}	(9.14)	2.31^{***}	(8.04)	2.39^{***}	(10.52)
Confidence	0.96	(-0.96)	0.95^{*}	(-2.12)	0.95^{**}	(-2.58)
Trial number	1.00^{*}	(-2.27)	1.00	(1.54)	1.00	(0.93)
Constant	1.11	(1.28)	0.84^{***}	(-3.76)	0.93^{*}	(-2.02)
Observations	2540		2912		6724	

Note. Odds Ratios; *z* statistics in parentheses, * $p < .05$, ** $p < .01$, *** $p < .001$. All variables are centered.

Influence of SVO

To put the observed effect of the last fixation on the likelihood to decide for the more prosocial option into context of another well studied effect, we used SVO as an additional behavioral predictor in the primary regression model. The results showed that, as in other studies, participants with a high SVO angle were more likely to make prosocial choices (OR = 1.01, z = 2.51, p = .012). In particular, that means that the pure individualist (SVO angle = 0°) made on average 8.25% fewer prosocial choices than an ideally prosocial (SVO angle = 45°) participant. Testing the effect of the last fixation on the subsequent choice in the interrupted (self-determined) trials, the analysis revealed that in case the prosocial option was attended to last, the odds ratio of choosing the prosocial option was 2.12 (z = 6.07, p < .001, self-determined: OR = 6.52, z = 9.20, p < .001). Specifically, attending the prosocial option last increased the probability of choosing it by 15.19% (self-determined: 36.35%). Investigating the influence of SVO angle further, we found that it did not have an impact on the size of the attention-choice relationship (OR = 1.01, z = 0.55, p = .583), and neither on the strength of the bottom-up effect of attention on choices (OR = 1.00, z = -0.46, p = .649) in the interrupted trials. Additionally, the results showed that SVO angle did not have an impact on whether a participant made a self-determined choice (OR = 1.00, z = -0.34, p = .737) or was timed out (OR = 1.00, z = 0.20, p = .839). See Table S19 for the complete analysis.

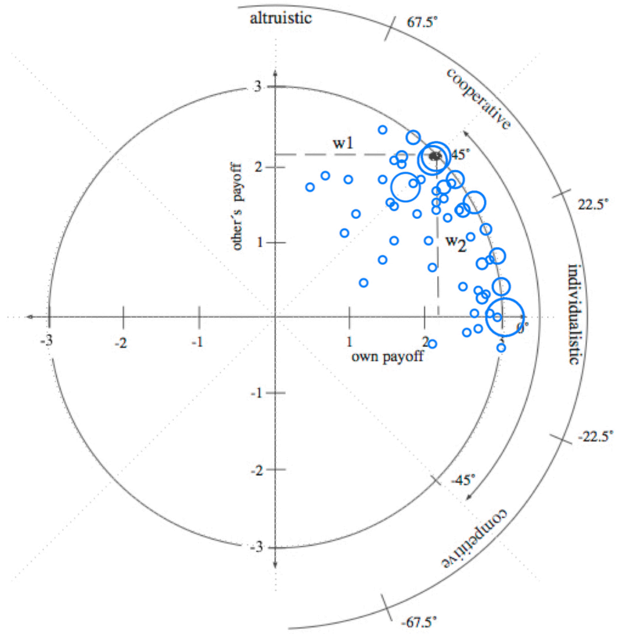

Figure S7. Participant's Social Value Orientation (SVO) in Study 1 according to the SVO Ring Measure. SVO angle is measured in degrees.

Table S19

Study 1: Choice of prosocial option predicted by SVO Angle for self-determined (A), interrupted (B) and all trials (C).

	(A) Self-determined		(B) Interrupted		(C) All trials	
	OR (prosocial)		OR (prosocial)		OR (prosocial)	
Last fixation prosocial	6.52^{***}	(9.20)	2.12^{***}	(6.07)	3.16^{***}	(10.38)
SVO Angle	1.01^{*}	(2.51)	1.01	(1.53)	1.01^{*}	(2.51)
Trial number	1.00	(-1.40)	1.00	(0.91)	1.00	(0.43)
Constant	0.99	(-0.04)	1.05	(0.33)	0.95	(-0.42)
Observations	1179		1404		3243	

Note. Odds Ratios; *z* statistics in parentheses, * $p < .05$, ** $p < .01$, *** $p < .001$.

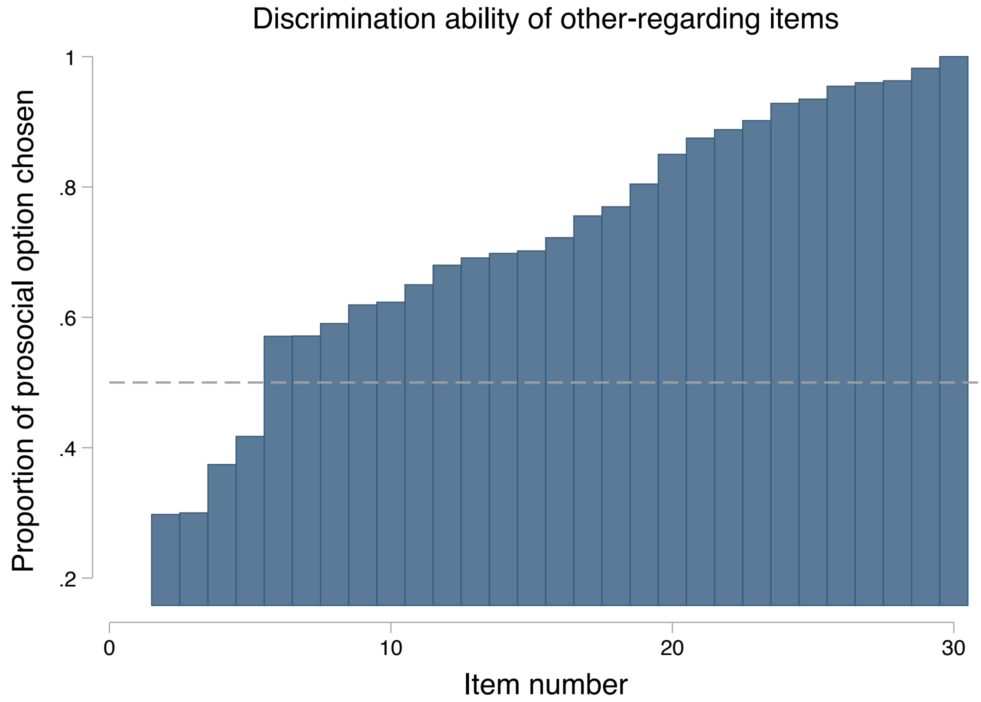

Figure S8. Distribution of prosocial choices for each other-regarding item. Dashed line at proportion = 0.5 indicates where the number of choices in favor of the prosocial and individualistic option was equal.

Table S20

Study 1: Separate analysis for other-regarding and moral choices. Choice of right option predicted by position of target for self-determined (A), interrupted (B) and all trials (C).

	(A) Self-determined OR (right option)		(B) Interrupted OR (right option)		(C) All trials OR (right option)	
	Social	Moral	Social	Moral	Social	Moral
Target right	0.43***	0.45***	2.85***	4.03***	1.08	1.26**
	(-4.99)	(-6.00)	(7.53)	(9.93)	(1.06)	(3.21)
Relative time	4.02***	4.16***	1.95***	2.84***	2.01***	2.74***
advantage right	(8.90)	(10.36)	(5.46)	(7.05)	(8.02)	(10.61)
Confidence	0.98	0.98	0.92*	0.98	0.96	0.98
	(-0.43)	(-0.46)	(-2.24)	(-0.63)	(-1.56)	(-0.84)
Trial number	0.99*	1.00	1.00	1.00	1.00	1.00
	(-2.52)	(-1.10)	(1.58)	(0.60)	(-0.27)	(0.46)
Constant	3.09**	2.41**	0.72	0.48**	1.29	1.04
	(2.94)	(2.66)	(-1.48)	(-2.83)	(1.47)	(0.18)
Observations	1211	1329	1464	1448	3356	3368

Note. Odds Ratios; *z* statistics in parentheses, * $p < .05$, ** $p < .01$, *** $p < .001$.

Table S21

Study 1: Likelihood for the classification as a self-determined choices (A) or a timeout (B) predicted by confidence level, importance, SVO angle, target choice, trial, position of chosen option and type of choice.

	Other-regarding choices				Moral choices			
	(A) OR (self-determined)		(B) OR (timeout)		(C) OR (self-determined)		(D) OR (timeout)	
Confidence level	1.32^{***}	(5.97)	0.91^{*}	(-2.42)	1.56^{***}	(9.26)	0.91^{*}	(-2.55)
Importance	1.00	(0.00)	1.00	(-0.04)	1.01	(0.20)	0.99	(-0.12)
SVO angle	1.00	(-0.34)	1.00	(0.20)	-		-	
Choice of target option	0.28^{***}	(-11.37)	0.51^{***}	(-5.78)	0.22^{***}	(-12.04)	0.34^{***}	(-8.32)
Trial number	1.01^{**}	(3.26)	1.00	(0.89)	1.01^{***}	(4.47)	1.00	(1.29)
Choice of right option	1.30^{*}	(2.06)	1.12	(1.02)	1.40^{**}	(3.15)	1.11	(0.87)
Prosocial option	1.35^{*}	(2.31)	0.84	(-1.57)	-		-	
Constant	0.13^{***}	(-5.89)	0.81	(-0.75)	0.05^{***}	(-7.55)	0.74	(1.09)
Observations	2583		2064		2777		2039	

Note. Odds Ratios; *z* statistics in parentheses, * $p < .05$, ** $p < .01$, *** $p < .001$.

Table S22

Study 1: Choice of right option predicted by last fixation for (A) self-determined choices, (B) interrupted choices and (C) all trials. Model (1) does not include trial number as a control variable, (2) controls for trial number and (3) includes an interaction between trial number and last fixation.

	(A) Self-determined					
	(1)		(2)		(3)	
Last fixation right	9.51***	(11.70)	9.45***	(11.65)	9.41***	(11.65)
Relative time advantage right	4.84***	(8.98)	4.85***	(9.09)	4.85***	(9.06)
Confidence	0.96	(-1.05)	0.96	(-1.01)	0.96	(-1.01)
Trial number	-		1.00*	(-2.21)	1.00*	1.00*
Trial number × last fixation right	-		-		1.00	(0.37)
Constant	0.51*	(-2.35)	0.62	(-1.55)	1.11	(1.28)
Observations	2540		2540		2540	
	(B) Interrupted					
	(1)		(2)		(3)	
Last fixation right	3.43***	(10.93)	3.44***	(10.96)	3.39***	(10.68)
Relative time advantage right	2.33***	(8.12)	2.33***	(8.18)	2.32***	(8.08)
Confidence	0.95*	(-2.16)	0.95*	(-2.17)	0.95*	(-2.25)
Trial number	-		1.00	(1.58)	1.00	1.00^{+}
Trial number × last fixation right	-		-		0.99**	(-2.90)

Constant	0.65^{**}	(-2.82)	0.59^{**}	(-3.16)	0.83^{***}	(-3.94)
Observations	2912		2912		2912	

	(C) All trials					
	(1)		(2)		(3)	
Last fixation right	4.36^{***}	(15.93)	4.37^{***}	(15.93)	4.37^{***}	(15.93)
Relative time advantage right	2.39^{***}	(10.59)	2.39^{***}	(10.57)	2.39^{***}	(10.58)
Confidence	0.95^{**}	(-2.62)	0.95^{**}	(-2.65)	0.95^{**}	(-2.67)
Trial number	-		1.00	(0.96)	1.00	(1.03)
Trial number × last fixation right	-		-		1.00	(-1.32)
Constant	0.65^{***}	(-3.30)	0.62^{***}	(-3.32)	0.92^{*}	(-2.12)
Observations	6724		6724		6724	

Note. Odds Ratios; *z* statistics in parentheses, for (3) all variables are centered, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$.

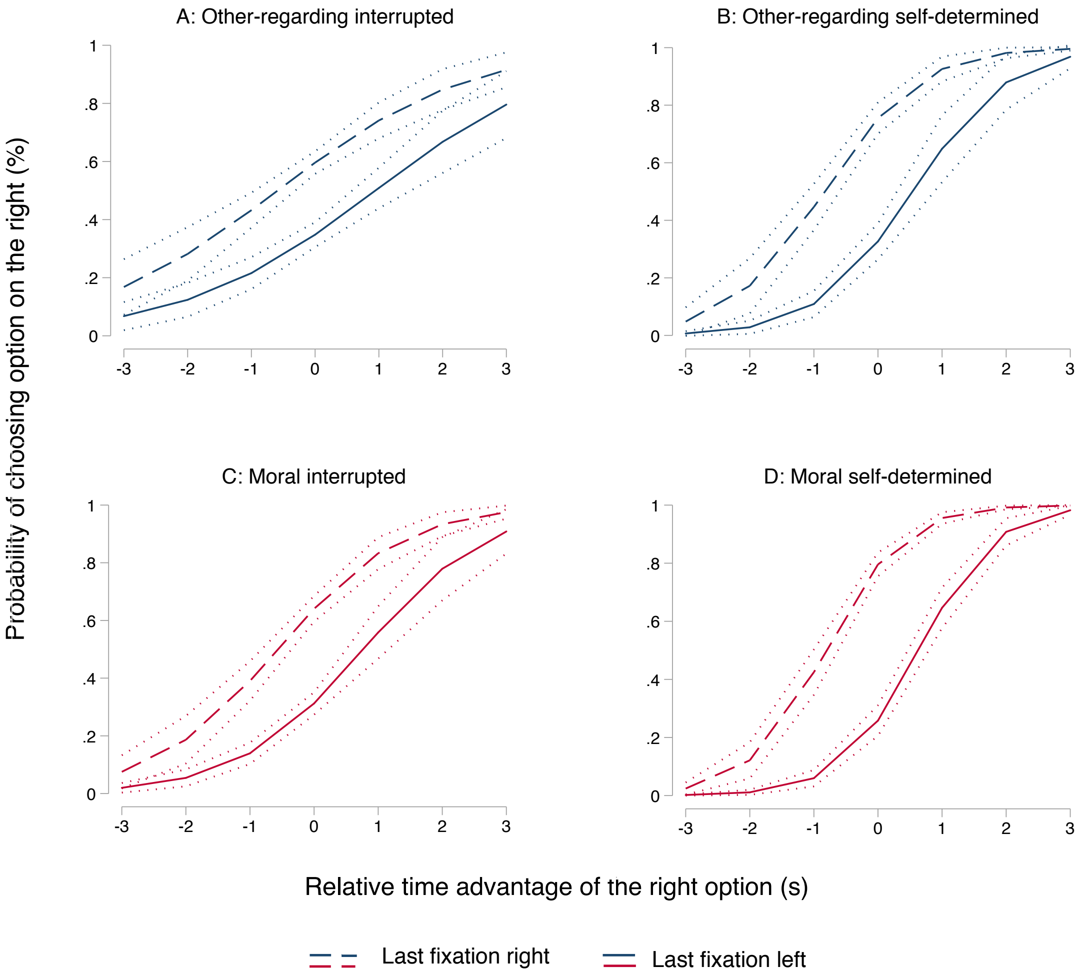

Figure S9. Study 1: Effect of direction of last fixation on choice probability for (A) other-regarding choices in interrupted trials, (B) other-regarding choices in self-determined trials, (C) moral choices in interrupted trials and (D) moral choices in self-determined trials. Dotted lines indicate 95% confidence intervals. N = 116.

Table S23

Study 1: Descriptive statistics of fixation number and duration for self-determined (A) and interrupted choices (B).

	(A) Self-determined	(B) Interrupted
Fixation number	19 (5)	23 (4)
Fixation duration (in ms)	108 (27)	106 (21)
Observations	2497	2912

Note. For fixation number, median and median average deviation (in parentheses) are reported due to a skewed distributions. For fixation duration, mean and standard deviation (in parentheses) are reported.

Table S24

Study 1: Repeated measured linear regression using interrupted choice / self-determined choice to predict (A) fixation number and (B) fixation duration.

	(A) Fixation number		(B) Fixation duration	
Interrupted	0.12^{***}	(5.84)	-0.01^{***}	(-3.80)
Constant	3.03^{***}	(125.13)	0.11^{***}	(60.23)
Observations	224		224	

Note. Unstandardized regression coefficients are reported, z in parentheses. Fixation number is log-transformed due to a skewed distribution. * $p < .05$, ** $p < .01$, *** $p < .001$.

Table S25

Study 1: The influence of semantic differences on choosing the target option and on information search

	(A) OR (target choice)		(B) Fixation number (log)		(C) Fixation duration	
Alternatives including verb	1.09	(1.22)	1.15^{***}	(16.32)	-0.01^{***}	(-8.89)
Constant	0.97	(-0.60)	2.96^{***}	(131.76)	-0.11^{***}	(-66.13)
Observations	5409		5409		5409	

Note. (A) Odds Ratios are reported, (B) and (C) unstandardized coefficients are reported; *z* statistics in parentheses, * $p < .05$, ** $p < .01$, *** $p < .001$.

Table S26

Study 1: The influence of semantic differences on choosing the right option and on the link between last fixation and subsequent choice.

	(A) Self-determined OR (right option)		(B) Interrupted OR (right option)		(C) All trials OR (right option)	
Alternative including verb	0.91	(-0.84)	1.07	(0.77)	0.97	(-0.46)
Alternative including verb × Last fixation right	0.92	(-0.35)	0.92	(-0.42)	0.88	(-0.90)
Last fixation right	9.44^{***}	(11.55)	3.44^{***}	(10.94)	4.37^{***}	(15.92)
Relative time advantage right	4.82^{***}	(9.01)	2.33^{***}	(8.09)	2.38^{***}	(10.41)
Confidence	0.96	(-1.02)	0.95^{*}	(-2.16)	0.95^{**}	(-2.66)
Trial number	1.00^{*}	(-2.18)	1.00	(1.57)	1.00	(0.96)
Constant	1.11	(1.24)	0.83^{***}	(-3.87)	0.93^{*}	(-2.07)
Observations	2540		2912		6724	

Note. Odds Ratios; *z* statistics in parentheses, * $p < .05$, ** $p < .01$, *** $p < .001$. All variables are centered.

Table S27

Study 1: Choice of right option predicted by character count and last fixation for self-determined (A), interrupted (B), and all trials (C).

	(A) Self-determined OR (right option)		(B) Interrupted OR (right option)		(C) All trials OR (right option)	
Character count	1.00	(-0.38)	1.00	(-0.25)	1.00	(-0.87)
Last fixation right	9.41***	(11.62)	3.44***	(10.90)	4.37***	(15.89)
Character count × Last fixation right	0.99	(-0.74)	1.00	(-0.52)	1.00	(-0.89)
Relative time advantage right	4.79***	(8.91)	2.31***	(7.93)	2.38***	(10.30)
Confidence	0.96	(-1.02)	0.95*	(-2.16)	0.95**	(-2.66)
Trial number	1.00*	(-2.19)	1.00	(1.57)	1.00	(0.96)
Constant	1.11	(1.28)	0.83***	(-3.84)	0.93*	(-2.06)
Observations	2540		2912		6724	

Note. Odds Ratios; *z* statistics in parentheses. All variables are centered, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$.

Table S28

Study 2: Choice of right option predicted by character count and last fixation for the autonomous (A) and exogenous group (B).

	(A) Autonomous OR (right option)		(B) Exogenous OR (right option)	
Character count	1.00	(0.82)	1.00	(0.08)
Last fixation right	10.86***	(10.98)	1.21*	(2.16)
Character count × Last fixation right	1.00	(-0.24)	0.99	(-1.25)
Relative time advantage right	4.26***	(8.75)	0.85**	(-2.65)
Confidence	0.96	(-1.07)	1.00	(-0.06)
Trial number	1.00	(0.20)	1.00	(0.29)
Constant	0.71***	(-5.25)	0.99	(-0.14)
Observations	2754		2932	

Note. Odds Ratios; *z* statistics in parentheses. All variables are centered, * $p < .05$, ** $p < .01$, *** $p < .001$.